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# COMPARATIVE SURVIVAL RATE STUDY (CSS) OF HATCHERY PIT TAGGED CHINOOK

Status Report For Migration Years 1997-2000 Mark/Recapture Activities

Annual Report 2001



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**COMPARATIVE SURVIVAL STUDY (CSS)  
of PIT Tagged Spring/Summer Chinook**

**Status Report for Migration Years 1997 – 2000  
Mark/Recapture Activities**

**Contract No. 00006203  
Project No. 1996-020-00**

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This report covers yearling hatchery chinook supplied by Idaho Department of Fish and Game (IDFG), U.S. Fish and Wildlife Service (USFWS), and Oregon Department of Fish and Wildlife (ODFW) for the CSS in migration years 1997 to 2000 at the following hatcheries. IDFG hatcheries include McCall (1997-2000), Rapid River (1997-2000), and Pahsimeroi (1997). USFWS hatcheries include Kooskia (1997), Dworshak (1997-2000), and Carson (1997-2000). ODFW hatcheries include Lookingglass (1997-1999) and Imnaha (1997-2000). We appreciate and extend thanks to the Fish and Wildlife agencies and all hatchery managers and staff personnel for their assistance in the planning, raising of, and recovery of study fish at the hatcheries.

From 1997 through 2000, approximately 800,000 hatchery spring/summer chinook were PIT tagged by State and Federal personnel for the CSS Program. This required a lot of time and effort from individual marking crews to complete tagging of these fish. The USFWS Dworshak Fisheries Resource Office (FRO) personnel PIT tagged fish at Dworshak and Kooskia hatcheries while the Vancouver, Washington, FRO personnel marked fish at Carson Hatcheries. PIT tagging at IDFG hatcheries was completed with supervision provided by the IDFG office in Lewiston, Idaho. Chinook at the Lookingglass complex were PIT tagged by ODFW personnel from the Northeast District fisheries office in LaGrande, Oregon. We thank the field supervisors and crews for an excellent job in completing the PIT tagging operations at these hatcheries.

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## EXECUTIVE SUMMARY

The Comparative Survival Study (CSS) was initiated in 1996 as a multi-year program of the fishery agencies and tribes to estimate survival rates over different life stages for spring and summer chinook (hereafter, chinook) produced in major hatcheries in the Snake River basin and from selected hatcheries in the lower Columbia River. Much of the information evaluated in the CSS is derived from fish tagged with Passive Integrated Transponder (PIT) tags. A comparison of survival rates of chinook marked in two different regions (which differ in the number of dams chinook have to migrate through) provides insight into the effects of the Snake/Columbia hydroelectric system (hydrosystem). The CSS also compares the smolt-to-adult survival rates (SARs) for Snake River chinook that were transported versus those that migrated in-river to below Bonneville Dam. Additional comparisons can be made within in-river experiences as well comparison between the different collector projects from which smolts are transported. CSS also compares these survival rates for wild Snake River spring and summer chinook. These comparisons generate information regarding the relative effects of the current management actions used to recover this listed species.

Scientists and managers have recently emphasized the importance of delayed hydrosystem mortality to long-term management decisions. Delayed hydrosystem mortality may be related to the smolts' experience in the Federal Columbia River Power System, and could occur for both smolts that migrate in-river and smolts that are transported. The CSS PIT tag information on in-river survival rates and smolt-to-adult survival rates (SARs) of transported and in-river fish are relevant to estimation of 'D', which partially describes delayed hydrosystem mortality. 'D', or differential delayed mortality, is the differential survival rate of transported fish relative to fish that migrate in-river, as measured from below Bonneville Dam to adults returning to Lower Granite Dam. A 'D' equal to one indicates that there is no difference in survival rate after hydrosystem passage, while a 'D' less than one indicates that transported smolts die at a greater rate after release, than smolts that have migrated through the hydrosystem. While the relative survival rates of transported and in-river migrants are important, the SARs must be also be sufficient to allow the salmon to persist and recover (Mundy et al. 1994). Decreased SARs could result from delayed hydrosystem mortality for either transported or in-river migrants, or both.

Major objectives of CSS include: (1) development of a long-term index of transport SAR to in-river SAR for Snake River hatchery spring and summer chinook smolts measured at Lower Granite Dam; (2) develop a long-term index of survival rates from release of smolts at Snake River hatcheries to return of adults to the hatcheries; (3) compute and compare the overall SARs for selected upriver and downriver spring and summer chinook hatcheries; (4) begin a time series of SARs for use in hypothesis testing and in the regional long-term monitoring and evaluation program; (5) evaluate growth patterns of transported and in-river migrating smolts, and of upriver and downriver stocks. Primary CSS focus in this report for the 1997-1999 migration years included hatchery chinook tasks for objectives 1, 4 and 5.

Another goal of CSS was to help resolve uncertainty concerning marking, handling and bypass effects associated with control fish used in National Marine Fisheries Service's (NMFS) transportation research and evaluation. Significant concern had been raised that the designated "control" groups, which were collected, marked and released at dams, did not experience the same conditions as the in-river migrants which were not collected and bypassed under existing management, and that the estimated ratios of SARs of transported fish to SARs of control fish may be biased (Mundy et al. 1994). Instead of marking at the dams, as traditionally done for NMFS' transportation evaluations, CSS began marking sufficient numbers of fish at the

hatcheries and defining in-river groups from the detection histories at the dams (e.g., total arrivals, never detected, detected one or more times).

The CSS PIT-tagged and released annually more than 200,000 smolts from Snake River hatcheries (primarily Dworshak, McCall, Rapid River, Imnaha and Lookingglass) and 5,000-13,000 smolts from a downriver hatchery (Carson) in 1997-1999. PIT-tagged smolts from the Snake River are detected in collection systems at Snake and Columbia River dams and diverted into transportation or bypassed to the river according to the annual study design. Detection histories are used to estimate numbers of smolts in in-river and transport categories, and to estimate survival between release and the first dam encountered (Lower Granite Dam), and from Lower Granite Dam to subsequent dams.

In-river groups of Snake River hatchery chinook in 1997-1999 were those smolts that were never collected or bypassed at Snake River collector dams ( $C_0$ ) and smolts that were collected and bypassed at one or more Snake River collector dams ( $C_1$ ). Hatchery chinook smolts transported from Lower Granite Dam ( $T_{lgr}$ ) were the primary transport group evaluated in 1997-1999, although we also evaluated transportation from all projects ( $T_0$ ). Returning PIT tagged adults are detected at Lower Granite Dam and assigned to appropriate in-river and transport groups. SARs (measured from smolts at Lower Granite to adult returns to Lower Granite) were calculated for transport and in-river groups, and ratios of transport SAR to in-river SAR were analyzed for each hatchery and year. In addition, we estimated the SAR from below Bonneville Dam back to Lower Granite Dam for both transported groups and in-river groups. These SARs provide information about the delayed impacts of the hydrosystem on survival rates that occur in the estuary and ocean (referred to as delayed hydrosystem mortality). Scales sampled from returning adult hatchery chinook were aged, and early ocean growth was compared between in-river and transported hatchery chinook as a possible mechanism leading into differences in delayed mortality in the different groups.

The CSS focus to date has been on hatchery spring and summer chinook, in part, because of the extremely low abundance of wild Snake River stocks. However, evaluating smolt mitigation and recovery strategies by tracking the performance of wild spring and summer chinook has been a CSS study objective since the beginning, and recommended in project reviews by the Independent Scientific Advisory Board. In addition, it is important to evaluate the extent to which response of hatchery chinook to management actions can be used as a surrogate for wild chinook. This report incorporates available wild chinook PIT tag data from smolt migration years 1994-1999 to estimate wild chinook SARs, to compare wild chinook SARs between transportation and in-river migration, and to compare wild and hatchery chinook responses (T/I ratios, 'D' values) to management actions. CSS has proposed to PIT tag enough juvenile wild chinook for the 2002, 2003 and 2004 out-migrations to provide a comparison of SARs between transported and in-river wild Snake River migrants, as well as between Snake River and downriver wild stocks with similar life-history characteristics.

***The extent to which hatchery chinook can be used for a surrogate for wild chinook for survival over the different life stages is inconclusive from the 3 years of information where this comparison was possible.*** In 1997, wild chinook exhibited quite different in-river survivals, LGR-LGR SAR<sub>T0</sub>, BON-LGR SAR<sub>T0</sub>, LGR-LGR SAR<sub>C0</sub>, BON-LGR SAR<sub>C0</sub>, and T/I than hatchery chinook ('D' values were similar). However, this year had the lowest sample sizes and likely least precise estimates for wild fish, of the 3 years evaluated. Differences between hatchery and wild chinook survival rates were not as pronounced in 1998 and 1999, but were still considerable.

***SARs of transported and in-river migrants were much less than 2-6% SARs needed to recover Snake River spring/summer chinook (Marmorek and Peters 1996).*** The average LGR-LGR SAR of wild chinook between 1994-1999 was approximately 0.85%. The average LGR-LGR SAR for hatchery chinook was 1.0% and 0.8% for transported and in-river migrants, respectively between 1997-1999.

***Modest transportation benefits were evident for Snake River hatchery chinook in 1997-1999.***

The CSS study design focused on estimating transport SAR ( $T_{igr}$ ) from the upper Snake River dam in these years, however we also estimated transport SAR from all projects ( $T_0$ ) to simulate actual management operations. The geometric mean ratio of transport LGR-LGR SAR ( $T_0$ ) to in-river LGR-LGR SAR ( $C_0$ ), or the  $T_0/C_0$  ratio, estimated by CSS was 1.26 for hatchery chinook in 1997-1999. Approximately a third of the  $T_0/C_0$  estimates for individual hatcheries and years were significantly greater than 1.0 although confidence intervals were large. The  $T_{igr}/C_0$  was generally higher than the  $T_0/C_0$  ratio with the geometric mean between 1997-1999 equal to 1.6. Starting in smolt migration year 2000, the CSS began diverting hatchery chinook to transportation from all collector projects to provide transport SAR estimates that better match actual management operations.

***Little or no transport benefits were evident in most years for Snake River wild chinook based on available PIT tag data, 1994-1999.***

The overall geometric mean  $T_0/C_0$  ratio was 1.23 for 1994-1999. The  $T_0/C_0$  ratio for 1994 (3.19) was over twice as high as the next highest value. If this value was excluded the geometric mean  $T_0/C_0$  ratio was 1.01. In 4 of the 6 years analyzed  $T_0/C_0$  ratio for wild fish was less than 1.0. Small sample size and past research operations that bypassed most PIT-tagged wild chinook (whereas untagged smolts were transported) somewhat limit inferences from the T/I estimates for 1994-1999. The CSS project has proposed expanded sampling for wild chinook and changes in research protocols to better represent actual transportation management for 2002-2004.

***Delayed hydrosystem mortality was evident for transported Snake River hatchery chinook smolts, which died at a greater rate after release than hatchery smolts that migrated through the hydrosystem in 1997-1999.*** The geometric mean ratio of the BON-LGR SAR of transported chinook ( $T_0$ ) to in-river chinook ( $C_0$ ), or 'D', for CSS hatchery chinook was 0.62 for 1997-1999. 'D' values were highly variable between hatcheries and years. 'D' values estimated with the  $T_{igr}$  were generally higher with the 1997-1999 geometric mean equal to 0.77.

***Delayed hydrosystem mortality was evident for transported Snake River wild chinook smolts, which died at a greater rate after release than wild smolts that migrated through the hydrosystem in 1994-1999.*** The geometric mean 'D' for wild chinook was 0.57 for 1994-1999. The 1994 'D' value (0.96) was much greater than the other years in this study. The geometric mean 'D' value excluding 1994 was 0.51. This 'D' value is considerably lower than the 'D' of 0.7 used in NMFS' 2000 Biological Opinion.

***The CSS found evidence that migrating through one or more projects before being transported resulted in higher delayed hydrosystem mortality than being transported at the first collector project, LGR dam, for hatchery chinook in 1997-1999.*** The geometric mean  $T_{igr}/T_0$  ratio was 1.24 between years and hatcheries. These ratios were generally not statistically significant but were greater than 1.0 in 12 out of 16 cases suggesting statistical power was low for the effect size. A lower SAR for chinook transported from all projects than the SAR from chinook transported at LGR could not be explained by mortality incurred during migration to the lower projects. Therefore, differences in SARs are likely due to a decrease in survival after the hydrosystem

resulting from the increase in stress from migrating through more than one project before being transported.

***The CSS found evidence of delayed hydrosystem mortality of in-river migrants associated with collection and bypass at Snake River dams in 1997-1999 for hatchery chinook.*** In-river migrant hatchery chinook that were collected and bypassed at one or more Snake River collector dams ( $C_1$ ) had a SAR only 72% as high as the SAR of hatchery chinook that were not collected and bypassed at Snake River collector dams ( $C_0$ ). The  $C_1/C_0$  ratio was less than 1.0 in 14 out of 16 cases. The confidence intervals often overlapped, but  $C_0$  was significantly greater than  $C_1$  in 5 cases. Group  $C_0$  best represented in-river migrants under management operations for 1997-1999 because most of the untagged smolts (i.e., the run at large) that were collected at Snake River dams (Lower Granite, Little Goose, Lower Monumental) were transported from these projects, rather than bypassed. Because the direct mortality of going through a dam undetected (through a combination of turbine and spillway routes) is generally higher than going through detected (through the bypass system), the decrease in SAR for the  $C_1$  group can only be explained by the decrease in survival after smolts migrate through the hydrosystem.

***Scale pattern analysis of Snake River hatchery chinook adult returns did not reveal differences in early-ocean growth rates between transported and in-river migrants in return years 1998-1999.*** Reduced early-ocean growth cannot be ruled out for either transportation or in-river migration, however, because CSS could sample only the survivors (returning adults).

## INTRODUCTION

Snake River salmon and steelhead have undergone precipitous declines since the late 1960's coinciding with the development of the lower Snake River hydroelectric system. Several management actions were implemented to mitigate for the expected losses upon completion of the hydrosystem. These actions included increased hatchery production, reductions in harvest, screening of water diversions, and adult and juvenile passage improvements at the Columbia and Snake River dams. In addition, mass transportation of smolts in the lower Snake River was initiated in the late 1970's in an effort to reduce mortality of salmon and steelhead during downstream migration. Smolts are captured at Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMN), and occasionally at McNary Dam (MCN), transported in barges and trucks and released to below Bonneville Dam (BON), the last dam on the Columbia River, thereby circumventing direct mortality due to passage through the remaining hydroelectric projects and reservoirs.

Despite these efforts to mitigate or even halt the declines, Snake River stocks continued to plummet. In 1991, sockeye salmon were listed under the Endangered Species Act with spring/summer chinook, fall chinook, and steelhead listed soon afterward. In 1995, an analytical workgroup was created to evaluate the efficacy of alternative management actions on Snake River salmon and steelhead recovery. This process was referred to as the Plan for Analyzing and Testing Hypotheses (PATH) and was comprised of scientists from several federal, state, and tribal agencies. In addition, the National Marine Fisheries Service (NMFS) began a similar analysis for these and other listed stocks in the Columbia River Basin starting in 1999. NMFS created a matrix model to determine the life stage where managers should focus their efforts. These analytical processes were developed to guide future management actions used to recover endangered stocks. The basic information utilized to evaluate management alternatives for spring/summer chinook was redd counts that defined survival over the entire life cycle of the salmon described by the number of recruits per spawner. Further information was used to partition survival over different life stages throughout the life cycle such as: survival through the hydrosystem during the downstream migration (in-river survival or  $V_C$ ); smolt-to-adult survival (LGR-LGR SAR, based on the number of adults returning to LGR from a number of smolts leaving LGR); the relative LGR-LGR SAR (T/I ratio) between transported fish and fish migrating in-river; and the relative BON-LGR SAR between transported fish and in-river migrants ('D'), which describes the survival after passing the last dam on the hydrosystem but is a result from a fishes experience in the hydrosystem.

In-river survival estimates have been used to help describe the impact of the hydrosystem on downriver migratory stage of the salmon life-cycle. These survival estimates have also been useful in evaluating the success of mitigation measures and actions (e.g. flow augmentation, spill, transportation, etc.). In-river survival estimates have been estimated through mark-recapture models and through passage models (e.g. CRISP, FLUSH, SIMPAS). With the development of Passive Integrated Transponder (PIT) tags, more detailed mark-recapture estimates are now more feasible. Survival during transport has not been well studied but based on anecdotal evidence is thought to be 98%.

For several years the LGR-LGR SAR has been determined for both fish that have migrated in-river and fish that have been transported, estimated by marking smolts and observing the number returning as adults. This measurement includes survival through the hydrosystem and survival from after fish smolt pass BON until they return as adults to LGR. Between brood years 1962-1974, prior to the completion of the Snake River hydrosystem, LGR(or uppermost dam on the Snake before the completion of LGR dam) -BON SARs ranged from 0.57% to 8.55% and

averaged 5.2% (Petrosky et. al 2001). Between brood years 1975-1997 LGR-BON SARs have ranged from 0.28 % to 2.03 % and averaged 1.2% (Petrosky et. al 2001). PATH determined that in order for Snake River spring/summer chinook to meet the recovery goals the LGR-LGR SAR must range between 2% and 6% (Marmorek and Peters 1996). These SARs provide a context and a benchmark for current estimates for listed stocks.

For several years, evaluation of the efficacy of smolt transportation program was based on studies of “T/I” (transport/in-river) ratios. These mark-recapture studies compared LGR-LGR SAR (some were from LGS-LGR) of test fish, which were transported from an upper dam (usually LGR or LGS), to control fish, which migrated in-river through the hydrosystem. These studies estimated the relative effectiveness of transportation to improve survival rates over in-river migrants of smolts from the site where they were collected as juveniles back to LGR when they returned as adults. If T/I was significantly greater than 1.0, then transportation was considered to be beneficial to the population. Between 1971-1989, T/I ratios ranged between 0.72-3.74 (with the exception of T/I=13.04 in 1973, one of the lowest water year on record); however, considerable discussion surrounds the definition of a “true” in-river control thus affecting the value of T/I. While the T/I ratio provides a convenient measure to quickly assess the benefits of the transportation program, this relative measure does not describe whether transportation of smolts is sufficient to mitigate for the effects of the hydrosystem or recover stocks (Mundy et al. 1994).

In both PATH and CRI the determination of the management action most likely to lead to recovery was highly dependent on what was assumed about mortality that occurred outside the hydrosystem but was a result of a smolt’s experience in the hydrosystem. This mortality is referred to as delayed hydrosystem mortality and can occur for both smolt that migrate in-river and smolt that are transported (Budy et al. 2001). One such parameter that was utilized in both modeling forums that partially describes delayed hydrosystem mortality is referred to as ‘D’. ‘D’ is related to the T/I ratio, but compares the BON-LGR SAR of test fish, which were transported, to control fish, which migrated in-river through the hydrosystem. A ‘D’ equal to one indicates that there is no difference in survival rate (after hydrosystem passage), a ‘D’ less than one indicates that transported smolts die at a higher rate after release than smolts that have migrated through the hydrosystem, and a ‘D’ greater than one indicates that transported fish survive better after BON. Because smolts are not enumerated at BON, the BON-LGR SAR is estimated from the LGR-LGR SAR, estimates of “control” in-river survival rates (through the hydrosystem), and direct transport survival rates.

Based on analyses from both modeling forums, NMFS recently outlined the management action they believe will recover these endangered stocks described in the 2000 Biological Opinion on the Operation of the Federal Columbia River Power System (BiOp). NMFS suggested that under a certain sets of conditions (i.e. ‘D’ = 0.7 combined with no delayed mortality of in-river “control” fish) the Reasonable and Prudent Alternative (RPA) management action (to improve in-river migration conditions through increases in spill and flow) would provide nearly the same benefit as breaching of Lower Snake River dams. NMFS based this conclusion on analyses that estimated current in-river survivals, SARs, T/Is and ‘Ds’, determined from mark-recapture information based on tagged smolt from 1994-1997 (NMFS 2000). Responses of these variables to the implementation of the RPA are also likely to use tagging information.

Fisheries agencies and tribes developed a multi-year program, the Comparative Survival Study (CSS), to develop information to be used in monitoring and evaluating the impacts of the mitigation measures and actions (e.g., flow augmentation, spill, and transportation) under NMFS’ Biological Opinion to recover listed stocks. Much of the information collected in the CSS study

has been based on spring/summer smolts tagged with PIT tags. Each PIT tag has a unique code, and with PIT tag detectors installed in many of the Snake and Columbia River dams, a tremendous amount of information can be collected describing the survival and migration of smolts and adults. In addition, comparison of survival over different life stages between fish with different experiences in the hydrosystem (e.g. different routes of dam passage, transportation vs. in-river migrants, and migration through 8 dams versus downstream stocks that migrate through 3 dams) can also be evaluated. CSS has taken advantage of the large hatchery releases to obtain adequate sample sizes for these different comparisons. Since 1997 CSS has tagged over 800,000 hatchery smolts for evaluation of in-river survivals, SARs, T/I and D's. In addition, from 1994-1999 nearly 300,000 wild smolts have been PIT-tagged. By comparing these variables for both hatchery and wild groups, it is possible to determine if hatchery fish provide a reasonable surrogate for wild fish. If so, a relationship between the two groups can be developed, allowing us to use hatchery fish to track wild stocks in years where there are too few wild smolts to mark. The objectives of this study are as follows (those objectives and tasks addressed in this status report are bolded):

**1. Develop a long-term index of transport survival rate (smolt-to-adult) to in-river survival rate (smolt-to-adult) for Snake River hatchery spring and summer chinook smolts.**

**Task 1(a): Compute an annual ratio of transport survival rate to in-river survival rate (measured at Lower Granite Dam) with associated confidence interval.**

**Task 1(b): Test if the annual ratio of transport survival rate to in-river survival rate (measured at Lower Granite Dam) is greater than 1.5 with sufficient power to provide a high probability that the ratio is greater than 1.0.**

Task 1(c): In years when the NMFS transport study is in place, evaluate whether in-river controls obtained from fish PIT tagged at the hatcheries have higher smolt-to-adult survival rates to Lower Granite Dam than in-river controls obtained from migrating fish that were collected, handled, and PIT tagged at Lower Granite Dam.

**2. For Snake River basin hatcheries, develop a long-term index of survival rates from release of smolts at hatcheries to return of adults to hatcheries.**

Task 2(a): Partition survival rates (i) from hatchery (smolts) to Lower Granite Dam (smolts), (ii) from Lower Granite Dam (smolts) back to Lower Granite Dam (adults), and (iii) from Lower Granite Dam (adults) to the hatchery (adults).

Task 2(b): For the combined Snake River hatcheries, compute the annual survival rate of smolts transported at Lower Granite Dam to adult returns to the hatcheries.

Task 2(c): For the combined Snake River hatcheries, compute the annual survival rate of smolts migrating in-river to adult returns to the hatcheries.

Task 2(d): Explore the feasibility of increasing mark sizes to improve precision in the annual ratio of transport survival rate to in-river survival rate [Task 1(a)] measured back to the hatchery.

3. Compute and compare overall smolt-to-adult survival rates for selected upriver and down-river spring and summer chinook hatcheries.

Task 3(a): Compute annual hatchery survival rates (adjusted for terminal harvest rates) using both CWT and PIT tags for selected upriver and down-river hatchery stocks. Compare survival rates of CWT and PIT tag estimates. Estimate survival rates (smolt-to-adult) for these hatchery stocks from previous production type CWT releases.

Task 3(b): Compute an annual ratio of down-river hatchery survival rate to upriver hatchery survival rate (all measured at the hatcheries and adjusted for terminal harvest) with associated confidence interval.

Task 3(c): Test if the annual ratio of down-river hatchery survival rate to upriver hatchery survival rate (all measured at the hatcheries) is greater than 2.0 with sufficient power to provide a high probability that the ratio is greater than 1.0.

Task 3(d): Test, aggregately and individually, if the annual ratio of down-river hatchery survival rate to upriver hatchery's transported smolts survival rate (all measured at the hatcheries) is greater than 2.0 with sufficient power to provide a high probability that the ratio is greater than 1.0.

Task 3(e): Explore the feasibility of developing lower river wild index stocks (*e.g.*, Warm Springs, John Day, and Klickitat rivers) to measure smolt-to-adult survival rates. Note: this task is delayed until after 134.2 kHz PIT tag detection capability is available at Bonneville Dam for returning adults.

- 4. Begin a time series of smolt-to-adult survival rates** for use in the PATH hypothesis testing process and in the regional long-term monitoring and evaluation program, which is under development.

- 5. Evaluate growth patterns of transported and in-river migrating smolts**, and of upriver and down-river stocks.

**Task 5(a): Collect and catalog scales from PIT tagged adults detected at Lower Granite Dam adult trap or at the upriver hatcheries.**

Task 5(b): Coordinate with the down-river hatcheries to collect and catalog scales from CWT groups that are representative of the production lots from which the PIT tagged fish were taken.

In this document, we summarize CSS activities since 1997. We report the methods used to estimate in-river survivals, SARs, T/Is and Ds for both hatchery and wild PIT-tagged Snake River spring/summer chinook and the results from these studies. These analyses are based on PIT tagged hatchery chinook smolts released for the CSS in migration years 1997 to 2000, wild smolts tagged from 1994-1999, and on the available adult return data through July 10, 2001. This information addresses tasks of Objective 1 and the start of Objective 4. It is too early to perform the stated tests and comparisons of Objectives 2 and 3, since not enough completed three-year sets of adult returns, adjusted for harvest, are available for hatchery return analyses. Most CSS progress to date has been made in beginning to build the long-term time series of smolt-to-adult survival rates for Objective 4. The creation of this long time series of SAR data will be useful to

fishery managers regardless of the type of regional long-term monitoring and evaluation program adopted. From the conduct of this study over a series of years, in addition to obtaining estimates of smolt-to-adult survival rates, we should be able to investigate what factors may be causing differences in survival rates among spring/summer chinook with different experiences in the hydrosystem.

## METHODS

### Smolt PIT tagging

One major objective of the Comparative Survival Study was to “compute and compare overall smolt-to-adult survival rates for selected upriver and downriver spring and summer chinook hatchery stocks. To achieve this objective and the associated tasks, we were required to select hatchery programs that would allow the opportunity to mark sufficient numbers of smolts to give enough returning adult fish so that statistically rigorous smolt-to-adult survival rates could be computed to meet test requirements. The FPC and Oversight Team for the CSS looked at hatchery programs that would meet expected marking needs for the near-term and future.

For migration years 1997 to 2000, juvenile hatchery chinook were PIT tagged at four to six hatcheries in the Snake River basin and Carson NFH in the lower Columbia River. The Snake River basin hatcheries include McCall, Rapid River, Pahsimeroi, Dworshak, Kooskia, and Lookingglass (for separate stock releases on-site and at the Imnaha River acclimation pond). Initially, the lower Columbia River basin tagging efforts for the CSS included Round Butte and Cowlitz hatcheries, but these hatcheries were dropped after migration year 1997 due to fish disease problems (Berggren and Basham 2000). At all hatcheries used in this study, fish were obtained across as wide a set of ponds and raceways as possible to allow effective representation of production. Collected fish were anesthetized and implanted with an 11 mm PIT (passive integrated transponder) tag (Figure 1). PIT tags were applied with individual syringe injectors. The injector needles were disinfected with ethyl alcohol after each use to minimize the possibility of disease transmission between fish. Tag loss and mortality is monitored at each



Figure 1. PIT tagging yearling hatchery chinook in USFWS marking trailer for CSS.

hatchery. The tagging files are then uploaded to the regional PTAGIS database. At each hatchery, dead fish were removed from the respective raceways or ponds, and checked for PIT tags. The original tagging files were then adjusted to account for raceway or pond mortality. More details on the tagging and data handling operations at the individual hatcheries are presented in Part B of the CSS Status Report for Migration Years 1996-1998 (Berggren and Basham 2000). The same procedures were implemented for migration years 1999 and 2000. Numbers of PIT tagged fish released for each hatchery stock, along with dates and location of releases and tagging coordinators, are summarized in Appendix A. A brief description of each hatchery is presented in Appendix A Table A6.

In 1994-2000, wild smolts have been captured in seines and screwtraps in the Clearwater, Grande Ronde, Imnaha, Salmon, and mainstem Snake River by state and federal fisheries agencies and through the Smolt Monitoring Program (SMP). Collected fish were anesthetized and implanted with an 11 mm PIT tag in the same manner as described above for hatchery fish. After implantation PIT tags were scanned and recorded to a computer. The tagging files were then uploaded to the regional PTAGIS database.

## **Smolt in-river survival estimation**

### ***Hatchery group***

Estimates of survival for yearling chinook from CSS hatcheries in the Snake River basin were estimated to LGR tailrace and downstream through a complex of three reservoirs and dams to the tailrace of LMN. The CJS (Cormack [1964], Jolly [1965], Seber [1965]) methodology was used to obtain point estimates of survival with corresponding standard errors from release site to LGR tailrace (estimate  $S_1$  for first reach), LGR tailrace to LGS tailrace (estimate  $S_2$  for second reach), and LGS tailrace to LMN tailrace (estimate  $S_3$  for third reach). To obtain the survival estimates, program MARK (White and Burnham 1999) was used with both the design matrix and link function set to the identity matrix. These settings produce survival parameter estimates that are not constrained to the range 0 to 1, thus allowing standard errors to be calculated even when survival estimates slightly exceed 1.0 which occasionally happened in the shorter inter-dam reaches. When one of the survival components, either  $S_2$  or  $S_3$ , was estimated greater than 1.0, its value was deflated to 1.0 while the value of the other component was inflated to the value of  $S_2 \bullet S_3$ . The estimates of adjacent survival parameters are negatively correlated (i.e., if survival in the upstream reach is overestimated, then the survival in the downstream reach will be underestimated), and so the variance of  $S_2 \bullet S_3$  was computed as the variance of a sum of dependent random variables (Meyer 1975):

$$\text{var}(S_2 \bullet S_3) = (S_2 \bullet S_3)^2 \{ \text{var}(S_2)/(S_2)^2 + \text{var}(S_3)/(S_3)^2 + 2\text{cov}(S_2, S_3)/(S_2 \bullet S_3) \} \text{ (eq. 1)}$$

The computation used the identity  $\text{cov}(S_2, S_3) = \text{se}(S_2) \bullet \text{se}(S_3) \bullet \text{correlation}(S_2, S_3)$ .

A basic assumption of the multinomial model is that the marked fish are independently and identically distributed with a common survival probability, which we are trying to measure. When this and other model assumptions are violated the problem of “overdispersion” is encountered in which the data is more “dispersed” than is expected under the model (White, Burnham, and Anderson in press manuscript on Advanced features of program MARK). This condition causes the estimated variances to be too small. A variance inflation factor (Cox and Snell 1989), which in program MARK is estimated using the sum of the goodness-of-fit chi-squares divided by degrees-of-freedom from TEST 2 and 3 of program RELEASE, was multiplied by the variances

to adjust for the “overdispersion” problem. The point estimate of survival and corresponding adjusted standard errors for parameters  $S_1$ ,  $S_2$ , and  $(S_1 \bullet S_2)$  are presented in Appendix B along with the number of fish first-detected at LGR ( $m_{12}$ ), first-detected at LGS ( $m_{13}$ ), and first-detected at LMN ( $m_{14}$ ).

There are no direct measures of annual survival rate of in-river smolt through the hydrosystem that exactly match the reaches around which smolts are transported. Therefore, the annual survival experienced during migration from LGR-BON ( $V_C$ ) must be estimated by expanding the in-river reach survival rate estimates calculated from Cormack-Jolly-Seber (CJS) recapture models from LGR to LMN, MCN, or JDA to the reach from LMN, MCN, or JDA down to BON. We estimated survival to the furthest dam possible. In some cases, however, survival estimates had very large standard errors or were unidentifiable, and we then had to expand survival to these reaches as well as down to Bonneville Dam. At times a reach survival estimate was greater than 100%. This may occur if the previous reach survival estimate was too low. We did not constrain this estimate to 100% unless the standard error was greater than 10%. We did not use a reach survival estimate that had standard error greater than 25% of the estimate. We expanded the study reach to the LGR-BON reach by calculating a per-mile survival rate for the study reach and raising this rate to the power of mile in LGR-BON reach / mile in study reach. We believe the per-mile expansion is more appropriate than a per-project expansion (NMFS 2000) because John Day reservoir is over twice the length of the average upstream reservoirs.

### ***Wild group***

The method for estimating in-river survival for wild smolts is very similar to method used for estimating survival for hatchery fish. One difference is that  $S_1$  is not estimated for the wild group because wild smolts are marked at several locations above Lower Granite reservoir. Too few smolts are released from each site to allow an estimation of survival to LGR for each release site. Also, a pooled group from all release sites would exhibit too much overdispersion among groups to provide an accurate survival estimate. For hatchery fish,  $S_1$  is used to estimate the number of smolts arriving at LGR dam, but because this was not possible for wild smolts we used a different method to estimate this number for wild PIT tagged smolts (see Arrival numbers at LGR).

Along with multiple release sites, wild smolts are tagged and released at multiple dates throughout the migration season in contrast to hatchery releases that generally occurs in a single release. Because we are estimating annual SARs, T/I and ‘D’ values we must calculate an annual reach survival estimate based on the reach survival estimates from several wild release cohorts. Generally we used a weekly release of cohorts to estimate survival with the minimum number of 500 released smolts detected at LGR to define the release period to minimize the variance associated with small sample sizes. Near the end of the migration season in 1998 we combined releases over a 5-week interval (5/20-6/23) to meet this criteria, but because of the weighting procedure described below, this cohort had little influence on the annual average survival rate due to the small proportion of the population at large represented by this release cohort.

To calculate annual reach survival rate estimates from the weekly PIT tag data groups, each individual cohort survival rate estimate should be weighted to determine the appropriate contribution to the aggregate estimate. Sanford and Smith (2001) weighted the survival estimates based on daily cohorts by the inverse relative variance to arrive at an annual average survival rate. Weighting the individual cohort survival rate estimates by the inverse relative variance results in greater influence on the average annual survival for those cohorts with more precise survival rate estimates without biasing the weights by the survival rate estimates themselves (Sanford and Smith 2001).

Because the number of smolt PIT tagged weekly was not directly proportional to the total migration for that week (tagging of smolts was often limited due to logistical constraints) we believed that individual cohort survivals should also be weighted by the proportion of the non-tagged population migrating over that week relative to the total migration. The passage indices (PI) for wild yearling chinook, provided by Fish Passage Center (Portland, OR) were used to represent the population at large passing LGR. To create a relative passage distribution for the migration season, daily PIs are calculated at LGR by dividing the daily collection by the proportion of water passing through the powerhouse where sampling takes place. This adjustment accounts for the effects of spill, if present, under the conservative assumption that the proportion of fish passing through spill will be close to the proportion of water being spilled. The number of smolts, as measured by the PI for a given week, was divided by the total number of smolts for the season, to estimate the contribution of that weekly cohort in the annual survival rate. The result of using this weighting procedure is that cohorts that migrated during the peak migration would have a greater contribution to the average survival estimate than smolts migrating at either end of the migration distribution. The average annual survival rate is thus, the average of the weekly release cohorts weighted by the precision of the estimate (the inverse relative variance) and the contribution of the general population over the release period to the total migration season (PI).

The final difference between hatchery and wild in-river smolt survival estimates was that the adjustment for overdispersion described for hatchery estimates was not applied to wild fish. This correction was not made for wild fish because we did not need this component of variability to develop a Monte Carlo simulation of the confidence intervals surrounding SARs. Development of the confidence intervals for SARs, T/I, and Ds are much more complicated for wild fish because of the methods used to estimate the number of smolts arriving at LGR. Thus, we are currently developing a bootstrap method that is not yet complete, to develop the confidence intervals for these variable for wild fish. Other computational steps for estimating survival for wild fish were the same as methods used for hatchery fish including how reach survival estimates were expanded to estimate  $V_C$ .

### **Smolt allocation to transportation and in-river migration categories.**

Wild and hatchery smolts are PIT tagged and released above LGR. Smolts can pass a dam through 3 different routes of passage; over the spillway or into the powerhouse where they either go through the turbines or are diverted with screens and pipes into the collection and bypass facility. Those smolts that pass the dams over the spillway or through the turbines are not detected. The collection and bypass facilities are equipped with PIT tag detectors and record the smolts' identification number and the time and date they were detected. Smolts that are not PIT tagged and enter the collection facility are generally put in barges or trucks and transported to below BON. PIT-tagged smolts, however, are often returned to the river for study purposes. These routes of passage can occur at LGR, LGS, LMN, and MCN. Smolts can also go through by-pass facilities at JDA and BON also equipped with PIT tag detectors, although no transportation occurs at these projects.

A goal of the CSS was to estimate of SARs for both transported and in-river smolts. The study design to obtain precise estimates included obtaining a cumulative hatchery minimum of 43,000 PIT tagged smolts in the transport group and 64,500 PIT tagged smolts in the overall in-river group. These smolt numbers are geared to providing a minimum of 86 total adults for testing purposes in each returning group if conditions of historic low SAR's occur. Beginning in

migration year 2000, the routing scheme was modified in order to get a portion (50-75%) of CSS PIT tagged fish routed to transportation at all three transportation dams in the Snake River. The *multimon.exe* software has been successful in diverting the set proportion of CSS PIT tagged fish to transportation at the various dams. Use of the separation-by-code program does not impact the timed subsample being taken at these dams because it is in effect only during non-subsampling intervals.

For migration years 1997 to 2000, a portion (67-80%) of the CSS PIT tagged hatchery fish entering LGR collection facility have been diverted to transportation and the remaining proportion returned to the river using the separation-by-code technology. The proportion of fish to divert into transport at the various dams was adjusted in-season in 1998 and 1999 in an attempt to maintain a 40% transport and 60% in-river split in smolts in these groups. Because high flows and high spills in 1997 substantially reduced the numbers of PIT tagged study fish being detected at LGR and diverted to transportation, we began diverting additional CSS PIT tagged fish to transportation at LGS in 1998 and 1999. Routing a portion (67-75%) of the CSS fish to transport at LGS occurred for part of the migration seasons in 1998 and 1999 (ended May 9 in 1998 and began May 10 in 1999). Because PIT-tagged smolts are not transported in the same proportion as the non-tagged population that arrives in the collection facility and because PIT-tagged fish are transported at LMN as is the practice for the non-tagged population, these fish may not accurately represent the run-at-large transported fish.

For migration years 1994-1999 wild PIT-tagged fish were returned to the river at all collection facilities unless a timed subsample was obtained or if a malfunction in the flipgates occurred. All subsampled fish and fish entering the raceways during flipgate malfunctions were transported. Thus, transported PIT-tagged wild smolts may not accurately represent the non-tagged population.

### **Sampling smolts for physiological analyses.**

The University of Idaho Cooperative Fish and Wildlife Research Unit (UICFWRU), under a contract with the USACE, is conducting research on the changes in physiological condition of smolts as they migrate in-river past multiple dams through the lower Snake and Columbia rivers. The goal of this study is to follow known hatchery chinook populations through the hydro system. For migration years 1998 to 2000, the UICFWRU researchers have contributed 9,000 PIT tags to the CSS quotas of 45,000 PIT tagged fish at Dworshak, McCall, and Rapid River hatcheries to create a large pool of 48,000 PIT tagged fish at each hatchery. This higher release number of PIT tagged fish has provided the UICFWRU researchers with a large pool of candidate fish from which to draw their samples over the season without impact to the CSS. Results from this study are presented in a separate report by UICFWRU.

### **Estimating LGR-LGR smolt-to-adult survival rates (SARs)**

Because smolt are tagged and released at several locations above Lower Granite reservoir, and because smolt that enter the collection facility are counted at LGR, this dam has been used as a reference point to measure SARs. The first step to estimating SARs using PIT tag information is to estimate the total number of PIT-tagged smolt arriving at LGR. Next, a SAR from LGR back to LGR is estimated for the transported group and the in-river group. We define the transport and in-river groups through detections of PIT-tags recorded at all dams with collection/detection facilities. Because some of the smolts leaving LGR die before reaching the lower dams, we must

estimate the number of smolts required to pass LGR to produce the number of in-river and transported smolts that were first detected at the lower dams. We estimate the number of smolt passing LGR 'destined' to arrive at the lower projects by dividing the number of smolts arriving at the lower projects by the survival to those lower projects. In doing so, all smolts used to estimate a common SAR for all projects are reported in LGR equivalents for ease of interpretation. In addition, because PIT-tagged and non-PIT-tagged smolts are treated differently, SARs should be evaluated with smolt that have detection histories that are most similar to the non-PIT-tagged population. We calculate the SARs for either transported fish and in-river fish by summing the number of smolt detected at the relevant projects (in LGR equivalents) over the season and dividing this into the number of adults returning to LGR with the same detection history from that migration year. Adults are defined as  $\geq 4$  yr olds although we evaluated the impact of jacks on SARs for selected hatcheries. SARs in this report includes adult returns as of July 10, 2001. These are the general steps in estimating SARs for both wild and hatchery spring/summer chinook. Further detail is provided in subsequent sections below.

For wild fish we have reported the mean SAR, T/I, and D values between 1994-1999 and between 1995-1999. We believe that 1994 does not represent the current values under the Reasonable and Prudent Alternative (RPA) because this year was before implementation of the 1995 Biological Opinion RPA that calls for a spill and flow program to assist in-river migration. Analyses for the 2000 Biological Opinion used past years values to give an indication how the proposed RPA operations (same as 1995 RPA for spill and flow requirements) would affect the downstream migration. Because minimal spill was implemented in 1994, the majority of all non-detected in-river migrating spring/summer chinook had to pass all the projects through the turbines. Passing the dams through the turbines rather than over the spillway is thought to be a more stressful route of passage. This would likely result in higher delayed mortality of in-river migrants than has occurred since the spill program has been implemented. This is corroborated by D values approximately twice as high as has been observed since spill has been implemented. We do not believe that 1994 is representative of the intentions of the 1995 or 2000 RPA. However, the analyses used in the 2000 Biological Opinion did use the 1994 D value in their overall geometric mean D value despite the fact that the hydro system in 1994 was not operated under the RPA they were trying to characterize. For these reasons, we report T/I and D values with and without 1994.

### ***Arrival numbers at LGR***

To estimate the number of hatchery smolts arriving at LGR dam, we multiplied the number of smolts released,  $R_1$ , by the survival rate,  $S_1$ , estimated by the CJS. Because of the multiple sites that wild smolts are released this method is not applicable. Therefore, we used the methods described in Sandford and Smith (2001). This method estimates LGR arrivals as the summed daily passage estimates, which were calculated by dividing the passage index by daily detection efficiencies. This method defined a population known to be alive at LGR (by virtue of having been detected at LGS), and then determined the proportion of smolts in the sub-population that was detected at LGR. Corrections were made for proportions of detected smolts removed (transportation or unknown disposition) using 7-day running averages.

### ***Estimation of smolt numbers by category***

#### **Transport groups**

Because PIT-tagged smolts that are captured in the collection facilities are often returned to the river rather than transported as is done with non-tagged smolts, we must be concerned that the

PIT-tagged smolts selected to estimate T/I and ‘D’ best reflect how the run-at-large (non-tagged population) is treated. The PIT tag detection history that best represents the run-at-large of transported smolts is first detection at the site they were transported because in practice all non-tagged smolts entering the collection facilities were transported (with the exception of MCN after 1994). Using first time detections only for transported smolts prevents an inflation of the proportion of PIT-tagged smolts collected at lower projects because smolts that entered the collection facilities at the upper dams and returned to the river are not subsequently transported at lower projects.

Because fish transported at different transport sites appear to differ in their overall SAR (Bouwes et al. 1999), the estimate of  $SAR_T$  is affected by the collector projects selected. In the past,  $SAR_T$  has been based on the smolts transported at only LGR and LGS (NMFS 1999). However, in 1994-1998, smolts were also transported at LMN and MCN projects. To accurately portray transportation operations, all collection projects where smolts were collected and transported must be included. However, because the PIT-tagged fish have often been returned to the river the number of PIT-tagged smolts transported at some projects are underrepresented and must be adjusted to better reflect the run-at-large. Adjusting the proportion of the PIT-tagged smolts that were transported by the proportion of the run-at-large that was actually transported at each project can correct this bias. Let  $PA_j$  represent the actual proportion of all spring/summer chinook smolt (tagged, non-tagged, hatchery, and wild) arriving at a collector project ( $j$ ) that was transported. Let,  $PO_j$  represent the proportion of the all PIT-tagged wild or hatchery (depending on the group evaluated) spring/summer chinook arriving at a collector project that was transported. Therefore, the weights,  $w$ , applied to each  $SAR_{T,j}$  were

$$w_j = \frac{PA_j / PO_j}{\sum_j \frac{PA_j}{PO_j}} \quad (\text{eq. 2})$$

producing a  $SAR_T$

$$SAR_T = \frac{\sum_j w_j LGR_{A,j}}{\sum_j w_j LGR_{S,j}} \quad (\text{eq. 3})$$

where  $LGR_{A,j}$  is the LGR returning adults and  $LGR_{S,j}$  is the LGR equivalent smolts for each project  $j$ .

In order to report the number of smolts arriving at lower collection facilities in LGR equivalents, we must divide the number of first detected smolts that were transported by the survival to that facility. Thus, Group  $T_0$  consists of PIT tagged CSS smolts routed to the fish barge (or truck) at LGR or first-time detected PIT tagged smolts routed to transportation at either LGS, LMN, or MCN dams. The number of fish estimated in Group  $T_0$  is

$$T_0 = X_{12} + X_{102}/S_2 + X_{1002}/S_2S_3 + X_{10002}/S_2S_3S_4 \quad (\text{eq. 4})$$

(see textbox for definitions of symbols).

One potential problem of including all first detected and transported fish from all transport projects, is that for hatchery fish nearly all PIT-tagged smolts were diverted back into the river at LMN and MCN dams and wild PIT-tagged fish at all transport projects were diverted back to the river. Routinely, a group of smolts are diverted via the flip gates into the sample room where they are anesthetized, examined, and measured. These fish are then put into the raceways to be transported and are the only PIT-tagged hatchery fish that were transported at the LMN and MCN and the only wild PIT-tagged fish transported at all projects. Thus, some of the smolts have been unintentionally transported, and because of the additional handling, these smolts may not best represent the non-tagged population. In addition, the resulting diversions back to the river can create small sample sizes of smolts transported at these projects, and because of the weighting procedure described above these small samples (and likely imprecise estimates) have the ability to be influential on the overall  $SAR_T$ . To explore the influence of these potentially imprecise project specific SARs have on the overall  $SAR_T$ , we compare the  $T_0$  group to those transported at just LGR dam ( $T_{lgr}$ ) for hatchery fish. We created this group only for hatchery PIT-tagged fish because this was the only site where these fish were purposefully transported during the 3 yrs of the study; the probability of wild fish to get in the different transport projects were similar because these fish were never intentionally transported. The  $T_{lgr}$  group is simply equal to  $X_{12}$ . For hatchery groups we present both  $T_{lgr}$  and  $T_0$ , and for wild fish we only present  $T_0$ .

### **In-river groups**

Because PIT-tagged smolts must go through the collection facility to be detected, and all non-tagged smolts entering the detection facility are generally transported, only PIT-tagged smolts that have not been detected should be evaluated to represent SARs for in-river fish. To estimate the number of smolts that were not detected at any of the collector projects ( $C_0$ ), the number of smolts first detected (transported and non-transported) at LGR, LGS, LMN is subtracted from the total number of smolts estimated to arrive at LGR. Smolts detected at MCN, JDA, and BON are included in this group as fish entering the bypass facilities at these projects are generally are returned to the river. The number of fish estimated in Group  $C_0$  is

$$C_0 = R_1 S_1 - (m_{12} + m_{13}/S_2 + m_{14}/S_2 S_3) - 2\Delta_0 \quad (\text{eq. 5})$$

where  $2\Delta_0$  is the number of smolts in LGR equivalents removed in the Congelton study (see text box for definition of symbols).  $C_0$  was estimated in this fashion for both wild and hatchery PIT-tagged fish with one exception. In 1994, smolts detected at MCN were put into transportation, thus in this year only wild smolts not detected at LGR, LGS, LMN, and MCN were included in the  $C_0$  category. Considerable discussion as to the definition of what constitutes a “true” in-river control has occurred in the past (Mundy et al. 1994). Often, any smolt that migrated through the hydrosystem, regardless of their detection history, has been used to represent an in-river fish. However, evidence suggests that fish entering a collection facility and returned to the river have a lower probability of returning as an adult than fish that pass a dam through either spill or through the turbines (Budy et al. 2001, Sandford and Smith 2001). Therefore, to use these fish to represent in-river control fish would be misleading as smolts that enter the collection facility are almost always transported. In this study, we evaluate the SARs of hatchery fish that were detected one or more times while migrating through the Snake River hydrosystem and contrast these to SARs of hatchery fish that were never detected at these sites ( $C_0$ ). We refer to this group as the  $C_1$  group, which consists of PIT tagged smolts detected at one or more of the Snake River collector dams (LGR, LGS, or LMN) that continue to migrate in-river below LMN.  $C_1$  was not estimated for the wild PIT tagged smolts. The number of fish estimated in Group  $C_1$  is:

$$C_1 = (m_{12} - \delta_2) + (m_{13} - \delta_3)/S_2 + (m_{14} - \delta_4)/S_2 S_3 - 2\Delta_1 \quad (\text{eq. 6})$$

**Definitions of symbols:**

- $X_{12}$  = number transported at Lower Granite Dam  
 $X_{102}$  = number first-detected and transported at Little Goose Dam  
 $X_{1002}$  = number first-detected and transported at Lower Monumental Dam  
 $X_{10002}$  = number first-detected and transported at McNary Dam  
 $R_1$  = number of PIT tags released from hatchery for CSS  
 $S_1$  = estimated survival from hatchery release site to Lower Granite Dam tailrace  
 $S_2$  = estimated survival from Lower Granite tailrace to Little Goose Dam tailrace  
 $S_3$  = estimated survival from Little Goose tailrace to Lower Monumental Dam tailrace  
 $S_4$  = estimated survival from Lower Monumental Dam tailrace to McNary Dam tailrace  
 $m_{12}$  = number of fish first detected at Lower Granite Dam  
 $m_{13}$  = number of fish first detected at Little Goose Dam  
 $m_{14}$  = number of fish first detected at Lower Monumental Dam  
 $m_{15}$  = number of fish first detected at McNary Dam  
 $\delta_2$  = number of fish removed at Lower Granite Dam regardless of prior capture history (includes transported fish, site-specific mortalities, and unknown disposition fish)  
 $\delta_3$  = number of fish removed at Little Goose Dam regardless of prior capture history (includes transported fish, site-specific mortalities, and unknown disposition fish)  
 $\delta_4$  = number of fish removed at Lower Monumental Dam regardless of prior capture history (includes transported fish, site-specific mortalities, unknown disposition fish, and fish accidentally removed at Lower Monumental Dam and used in NMFS survival study at Ice Harbor Dam)  
 $\Delta_0$  = site-specific removals at dams below Lower Monumental Dam of fish not detected previously at a Snake River Dam (includes incidental fish transported at McNary Dam, fish purposefully removed and sacrificed at downstream dams for the UICFWRU study, and fish accidentally removed at John Day Dam and used in NMFS survival study at The Dalles Dam)  
 $\Delta_1$  = site-specific removals at dams below Lower Monumental Dam of fish previously detected at a Snake River Dam (includes incidental fish transported at McNary Dam, fish purposefully removed and sacrificed at downstream dams for the UICFWRU study, and fish accidentally removed at John Day Dam and used in NMFS survival study at The Dalles Dam)  
 Note: both  $\Delta_0$  and  $\Delta_1$  are inflated by a constant factor of 2 to offset the approximate 50% survival rate to the lower Columbia River of fish starting at Lower Granite Dam

***Confidence Intervals for Smolt Numbers by Category***

For hatchery fish we estimated the confidence intervals through Monte Carlo simulations around the components of SAR that are estimated, including in-river survivals and the number of smolts and adults in each category. The confidence intervals around estimated components of wild fish are also necessary but are more complex and have not been completed at time this report was written. The following description on the development of confidence intervals is for hatchery fish only.

The number of smolts in each category for a given hatchery and migration year is not a fixed number except in the case of Category  $T_{1gr}$ , which equals the count of fish actually transported at LGR. In the case of categories  $T_0$  and  $C_1$ , the known counts at certain dams must be expanded by the estimated survival to get to those dams from the LGR starting population. In the case of Category  $C_0$ , both the population at LGR must be estimated and from that estimate the known

counts at certain dams expanded by the survival rates to those dams from LGR, must be subtracted. In each of these cases the estimates of various reach survivals must be utilized, each with their own measure of uncertainty. In order to compute the confidence intervals about the population sizes of each of these categories, a Monte Carlo approach was used in which a value was randomly selected from the distribution of the respective survival parameter and applied to each equation for  $T_0$ ,  $C_1$ , and  $C_0$  as shown below for the  $j^{\text{th}}$  iteration of 1000. The random variable (rv), for the  $j^{\text{th}}$  iteration, is  $\mathbf{rv}(\mathbf{S}_2)_j = Z_j \bullet \mathbf{se}(\mathbf{S}_2) + \mathbf{S}_2$  where  $Z_j$  is randomly selected from the standardized normal distribution  $N(0,1)$ .

- The number of fish estimated in Group  $T_0$  for the  $j^{\text{th}}$  iteration is  

$$T_{0j} = X_{12} + X_{102}/\mathbf{rv}(\mathbf{S}_2)_j + X_{1002}/\mathbf{rv}(\mathbf{S}_2\mathbf{S}_3)_j \quad (\text{eq. 7})$$

- The number of fish estimated in Group  $C_{1j}$  for the  $j^{\text{th}}$  iteration is  

$$C_{1j} = (m_{12} - \delta_2) + (m_{13} - \delta_3)/\mathbf{rv}(\mathbf{S}_2)_j + (m_{14} - \delta_4)/\mathbf{rv}(\mathbf{S}_2\mathbf{S}_3)_j - 2\Delta_1 \quad (\text{eq. 8})$$

- The number of fish estimated in Group  $C_{0j}$  for the  $j^{\text{th}}$  iteration is  

$$C_{0j} = R_1 \bullet \mathbf{rv}(\mathbf{S}_1)_j - (m_{12} + m_{13}/\mathbf{rv}(\mathbf{S}_2)_j + m_{14}/\mathbf{rv}(\mathbf{S}_2\mathbf{S}_3)_j) - 2\Delta_0 \quad (\text{eq. 9})$$

The 95% confidence interval is obtained by ordering the resulting 1000 values of  $T_0$ 's,  $C_1$ 's, and  $C_0$ 's in ascending order and selecting the values in the 25<sup>th</sup> and 976<sup>th</sup> rank order positions as the lower and upper limits of the confidence interval, respectively.

### ***Recovery activities at Lower Granite Dam adult trap***

LGR is a primary upriver evaluation site for many objectives of the CSS. The adult fish passage facilities at LGR incorporate an adult fish trap located just off the main fish ladder. When trapping occurs, adult fish are diverted from the main fish ladder into a pool area where two false weirs, a metal flume, coded wire detectors, and PIT detectors are in line leading to the adult holding trap. Unmarked fish or fish not required to be diverted will drop back into the fish ladder, and continue up to the main fish ladder where they can exit to the forebay of the dam. The tag identification files for CSS PIT tagged chinook are installed in the Multimon program that allow the PIT tag detector to selectively trip a gate and shunt these fish to the holding trap. PIT tagged fish and CWT fish from other studies are also diverted to the holding trap. Two PSMFC personnel are hired under the CSS to assist NMFS with the adult fish handling at the trap. This allowed data acquisition to proceed in a timely manner with all the increased PIT tagged fish that return to LGR as a result of the CSS. As the floor of the trap is raised, marked fish voluntarily exit the trap and slide into a holding tank containing a mixture of water and an anesthetizing chemical (MS-222 or clove oil). This anesthetic brings the fish to an immobile condition and allows the handlers to examine the fish. NMFS and PSMFC employees checked by hand scanning all fish in the sample tank for the presence of a PIT tag. When a PIT tagged fish was detected, a laptop computer installed with the Multimon Program will automatically display the disposition of the sampled PIT tagged fish; i.e., whether it was a CSS chinook or a chinook from the NMFS transportation survival studies group or another study. The collected CSS chinook have length taken, determination of sex and fish condition (injury) made, and a collection of 6-8 scales taken from the left side of the CSS fish in a location anterior to the dorsal fin midway above lateral line (Figure 2). Once the fish data were recorded, each fish was shunted back to the off-ladder trap, where it could recover from the effects of the anesthetic. The fish could then continue up the off-ladder fishway to the main fish ladder and on upstream to the exit of the fish ladder. All sampled fish are entered on the PTAGIS database as recaptures at the LGR adult trapping facility.



Figure 2. Length, sex determination, and scale sample are take from CSS PIT tagged adult chinook at Lower Granite Dam trapping facility.

### *Assignment of returning adults to categories*

Returning adults are assigned to groups  $T_{lgr}$ ,  $T_0$ , and  $C_1$  based on which route of passage these fish took as smolts at the Snake River dams, and whether fish on a given route were actually being transported or returned-to-river during a particular period of time. Returning adults not detected at LGR, LGS, and LMN, regardless of any subsequent downstream detection, were assigned to Group  $C_0$  (except in 1994 where wild smolts detected at MCN were not included in this group). More details on the mechanics of assigning returning PIT tagged adults to the various categories are presented in Appendix F.

### *Calculation of confidence intervals for SARs*

The SAR for the life stage between smolts at LGR and adults at LGR were generated for categories  $T_{lgr}$ ,  $T_0$ ,  $C_1$ , and  $C_0$  for each migration year and hatchery stock separately. The number of adults within a particular category divided by the estimated number of smolts in that category provides the initial SAR point estimate. In order to determine a 95% confidence interval for this point estimate the following Monte Carlo approach was used. The number of adults returning for a particular group of fish may be viewed as simply one of many possible outcomes from the Binomial distribution of adult returns for a particular SAR rate. In other words, by setting “n” equal to the number of smolts in a particular category and “p” equal to the SAR point estimate for that category ( $p = \text{adults}/n$ , and  $q = 1 - p$ ), the distribution of 1000 possible adult returns was generated from the Binomial(n,p) distribution for that category. To obtain the distribution of adults needed, the normal approximation to the binomial was used where  $\mu = np$  and  $\sigma = \sqrt{npq}$ . For the jth iteration,  $rv(\text{adult})_j = Z_j \sqrt{npq} + np$  where  $Z_j$  is randomly selected from the standardized normal distribution  $N(0,1)$ . This produces the number of adults returning for the jth iteration. This number divided by the number of smolts calculated for the jth iteration produces the SAR survival rate for the jth iteration in each of the four categories,  $T_{lgr}$ ,  $T_0$ ,  $C_1$ , and  $C_0$ . At the same time during the jth iteration, the ratios of selected SAR's are being generated:  $SAR_{T_{lgr}}/SAR_{C_0}$ ;  $SAR_{T_0}/SAR_{C_0}$ ; and  $SAR_{C_1}/SAR_{C_0}$ . The 95% confidence interval is obtained by ordering the resulting 1000 outcomes of adults, SAR's, and ratios of SAR's in ascending order and selecting the values in the 25th and 976th rank order positions as the lower and upper limits of the confidence interval, respectively.

### Estimating the BON-LGR smolt-to-adult survival rates (SARs)

Methods to estimate LGR-LGR SARs for transported ( $SAR_T$ ) and in-river ( $SAR_C$ ) fish have been described above. This measurement of survival from smolts to adults includes survival rates through the hydropower system for transported ( $V_T$ ) and for in-river ( $V_C$ ) smolts as well as survival after smolts pass BON and return to LGR. The number of smolts passing BON dam is not observed. Therefore, to estimate BON-LGR SARs, the hydrosystem survival rate is removed from the LGR-LGR SAR values. For fish that migrate in-river the BON-LGR SAR is LGR-LGR  $SAR_C/V_C$ , where  $V_C$  is estimated through the CJS estimate expanded to the entire hydrosystem, and the BON-LGR SAR for transported fish is LGR-LGR  $SAR_T/V_T$  where  $V_T=0.98$ .

### Estimating T/I ratios

Above we described the methods to estimate SARs for different detection histories of smolts that migrated in-river and smolts that were transported. These methods produced a  $SAR_T$  for the  $T_{igr}$  and the  $T_0$  groups and a  $SAR_C$  for the  $C_0$  and  $C_1$  groups. To evaluate the relative SARs for fish that were transported to fish that migrated in-river we calculated a T/I ratio =  $SAR_T / SAR_C$  for the different combinations of transport and control groups. In addition, we estimated the relative performance of the  $T_{igr}$  and the  $T_0$  groups by estimating a  $T_{igr}/T_0 = SAR_{T_{igr}} / SAR_{T_0}$ . We also make a similar comparison with the  $C_0$  and  $C_1$  groups, estimating the  $C_1/C_0 = SAR_{C_1} / SAR_{C_0}$ .

### Estimating 'D'

'D' is the ratio of post-BON survival rate of transported fish to in-river fish. Thus,

$$D = \text{BON-LGR } SAR_T / \text{BON-LGR } SAR_C = \text{LGR-LGR } SAR_T / \text{LGR-LGR } SAR_C * V_C / V_T \quad (\text{eq. 10})$$

For example, if 100 smolt were collected at LGR dam for transportation with 100 % survival (value assumed in the CRI and PATH models is 98%) to their release below BON and another 100 smolt had to migrate through the hydrosystem with a 50% survival rate, one would expect 100 transported and 50 in-river smolt to arrive below the BON tailrace. One might also expect the number of adults to return from surviving smolts that were transported to also be twice as high as the number of adults returning from surviving smolts that had to migrate in-river. If true, this would suggest delayed mortality were equal between transported and in-river fish, and thus the ratio of the post BON survival or 'D' would equal 1.0 and the  $SAR_T/SAR_C$  or the 'T/I ratio' would equal 2.0. However, if the number of adults returning from surviving smolts that were transported were equal to the number of adults returning from surviving smolts that had to migrate in-river then this would suggest delayed mortality of in-river fish was half of the delayed mortality of transported fish and 'D' would equal 0.5 and the T/I would equal 1.0.

### Scale pattern analysis

To determine whether stress through the hydrosystem or transportation of smolts lead to differential growth rates between these groups we evaluated the scale patterns of returning PIT tagged adult hatchery chinook collected in return years 1998 and 1999. The analysis looks at growth during early ocean residence of returning adults from the transport and in-river groups. In addition, we analyzed whether smolts originating from Snake River hatcheries, which migrated through 8 dams, differed in early ocean growth rates than smolts originating from the Carson hatchery and migrate through BON. This analysis is present in Appendix D of this report.

## RESULTS

### Smolt PIT tag releases

The number of hatchery chinook PIT tagged at each hatchery for the CSS is presented in Appendix A (Tables A-2 to A-5) along with dates of tagging and dates of release. Approximately 200,000 Snake River basin fish were released each year, except in 2000 when Lookingglass Hatchery production was discontinued. Release numbers at Carson Hatchery have increased from approximately 5,000 to 15,000 fish over the four years. The set of Snake River hatcheries used in the CSS accounts for about 80% of overall hatchery production in that basin.

For migration years 1994 to 1999, a total of 284,020 wild spring/summer chinook were PIT tagged in the Snake River basin. Nearly half (49.1%) of the wild chinook PIT tagged over this six years were tagged in the Salmon River basin. The remaining wild chinook smolts were PIT tagged in the Grande Ronde River basin (18.7%), Clearwater River basin (18.6%), Imnaha River basin (10.7%), and mainstem Snake River at Lewiston Idaho (3.0%). Approximately 72% of wild chinook tagged were tagged as parr collected the prior summer or in migrant traps during the fall months. The remaining 28% of wild chinook were tagged as smolts during the spring migration season. See Appendix A Table A-1 for a further breakdown into the sites within the various basins where the PIT tagged wild chinook were released. In 1994, 1995, 1998, 1999 enough wild spring/summer smolts were PIT tagged to produce nearly 20,000-35,000 smolts arriving at LGR (Table 1). These numbers are less than half of 1996 levels and much less than 1997 levels.

Table 1. The number of PIT-tagged wild smolts arriving at LGR dam, smolts transported at all projects upon first detection,  $T_0$ , (weighted by the proportion actually transported), smolt that migrated in-river and never detected above MCN dam,  $C_0$ , and the returning adults in the  $T_0$  and  $C_0$  groups.

Year	Smolts				Adults	
	Total tagged	LGR arrival	$T_0$	$C_0$	$T_0$	$C_0$
1994	54,128	18,986	4,466	3,899	11	6
1995	77,258	21,644	2,484	1,678	8	10
1996	21,997	8,338	483	1,760	2	6
1997	9,998	3,264	254	910	4	16
1998	35,472	18,603	1,321	3,268	15	42
1999	85,169	35,317	1,945	4,040	39	78

### In-river survivals

The point estimate of in-river hatchery survival and corresponding adjusted standard errors for parameters  $S_1$ ,  $S_2$ , and  $(S_1 \bullet S_2)$  are presented in Appendix B along with the number of fish first-detected at LGR ( $m_{12}$ ), first-detected at LGS ( $m_{13}$ ), and first-detected at LMN ( $m_{14}$ ).

In 1997 LGR-BON survivals ( $V_C$ ) ranged from 0.269 for Dworshak hatchery smolts to 0.538 for McCall hatchery smolts based on a per mile expansion (Table 2). In 1998 and 1999,  $V_C$  were higher and had a narrower range than 1997 with 1998 ranging from 0.423-0.581 and 1999 ranging from 0.550-0.788 (Table 2).

Table 2. Estimates of survival through the entire hydrosystem ( $V_C$ ) for hatchery and wild smolts with the percent difference observed for wild smolts relative to hatchery smolts.

Hatchery	1997	1998	1999
Rapid River	0.332	0.581	0.705
McCall	0.538	0.551	0.788
Dworshak	0.269	0.470	0.569
Imnaha	0.312	0.531	0.640
Lookingglass	0.403	0.423	0.550
Pahsimeroi	0.438		
Hatchery Average	0.382	0.511	0.650
Wild	0.483	0.607	0.641
Wild percent difference <sup>1</sup>	26%	19%	-1.4%

<sup>1</sup> The percent difference of wild fish relative to hatchery fish is expressed as  $(\theta_{\text{wild}}/\theta_{\text{hatchery}} - 1) * 100\%$  where  $\theta$  represents the variable of interest  $V_C$ .

$V_C$  for wild smolts were lower in 1994, 1995, and 1996 (0.296, 0.456, 0.346, respectively) than in 1997-1999 (Table 2). The pattern of smolt LGR-BON in-river survival rate estimates ( $V_C$ ) for hatchery and wild fish were similar with 1999 survival rates greater than 1998 greater than in 1997. In 1997,  $V_C$  was higher for wild fish than for the average hatchery  $V_C$  and greater than  $V_C$  for all individual hatcheries except for McCall hatchery smolts. In 1998,  $V_C$  for wild fish was also greater than average hatchery and greater than  $V_C$  of individual hatcheries. In 1999, the average hatchery and wild  $V_C$  were nearly identical although McCall hatchery survival rates were considerably higher (Table 2).

### Hatchery smolt migration timing at Lower Granite Dam

There has been a fairly consistent migration timing pattern at LGR Dam for the hatcheries used in the CSS. In each year, Lookingglass Hatchery chinook tended to migrate earlier than the other hatchery fish, with the exception of a very early migration of Dworshak Hatchery chinook in 1998 (see migration timing plots in Appendix C). As shown in Table 3, Lookingglass Hatchery is the only hatchery consistently having over half its migration past LGR Dam occurring in April, and Dworshak Hatchery did so in 1998.

### Estimated smolt numbers in the transport and in-river categories

The actual number of hatchery smolts in Category  $T_{\text{lgr}}$  and estimated number of smolts in each of the remaining three categories  $T_0$ ,  $C_1$ , and  $C_0$  are presented by hatchery in the following four Appendix B tables grouped by migration year (Table B-1 to B-4 for migration years 1997 to 2000, respectively). The number of fish in Category  $T_0$  from LGS and LMN has increased from migration year 1997 to 2000 because in each year we increased the proportion of CSS PIT tagged fish purposefully being routed to transportation at those sites from 0% in 1997 to 50-60% in 2000. From the total CSS PIT-tagged hatchery smolts transported, 95% were transported at LGR in 1997; 74% for Dworshak Hatchery and 85-89% for the other hatcheries in 1998; 87% for Lookingglass Hatchery and 45-57% for all other hatcheries in 1999; and 53-66% for all hatcheries in 2000. Therefore, the proportion PIT-tagged smolt contribution at each of the three

Table 3. Dates of 10%, 50%, 90% passage of smolts from Snake River hatcheries at LGR dam.

<b>Migration Year</b>	<b>Hatchery</b>	<b>10%</b>	<b>50%</b>	<b>90%</b>
1997	Rapid River H	4/24	5/07	5/20
	McCall H	4/27	5/10	5/16
	Dworshak-Kooskia H	4/27	5/12	5/19
	Imnaha AP	4/26	5/06	5/15
	Lookingglass H	4/19	4/28	5/09
	Pahsimeroi H	4/28	5/12	5/23
1998	Rapid River H	4/24	5/03	5/10
	McCall H	4/28	5/06	5/14
	Dworshak H	4/11	4/23	5/02
	Imnaha AP	4/24	5/02	5/09
	Lookingglass H	4/19	4/26	5/04
1999	Rapid River H	4/26	5/09	5/22
	McCall H	5/02	5/16	5/26
	Dworshak H	4/25	5/06	5/21
	Imnaha AP	4/30	5/11	5/21
	Lookingglass H	4/15	4/25	5/02
2000	Rapid River H	4/25	5/04	5/12
	McCall H	4/23	5/09	5/22
	Dworshak H	4/23	5/03	5/12
	Imnaha AP	4/24	5/04	5/12

Snake River transportation sites is not equivalent to the actual proportion from these three sites in the total transportation numbers for a given migration year. The category with the greatest width in its 95% confidence interval is Category C<sub>0</sub>, as would be expected due to the greater number of estimated survival components required in the estimation of its smolt numbers.

For wild spring/summer chinook, the numbers of first detected transported (T<sub>0</sub>) smolts or undetected smolts while migrating through the hydrosystem (C<sub>0</sub>) were greatest in the 1994, 1995, 1998, and 1999 (Table 1). Although, 1997 had the lowest number of tagged smolts, the number of returning adults was higher than in the previous years. The number of smolts transported at all projects was extremely low in 1996 and 1997.

#### **Adult (and jack) returns to Lower Granite Dam adult trap**

The CSS PIT tagged hatchery chinook that migrated out as smolts in 1997 to 1999 and returned as jacks and adults to LGR in 1998 to July 10, 2001 (3:33 P.M.) are presented in Table 4. Adult (2-and 3-ocean adult fish) return numbers for migration years 1997 and 1998 are complete; however, only the 2-ocean adult fish are available for migration year 1999. But even without the 3-ocean adult fish for migration year 1999, the results reported for SAR's are unlikely to change much. With the completed adult return data for migration years 1997 and 1998, the percentage of 2-ocean fish in the total adult return was 93.8% and 93.3%, respectively. Reporting of returning jacks from migration year 2000 will be deferred until the 2-ocean returns are completed next year.

Table 4. Number of CSS PIT tagged hatchery spring/summer chinook jacks and adults returning to Lower Granite Dam per category and migration year.

Migration Year	Hatchery	Category T <sub>lgr</sub>		Category T <sub>0</sub>		Category C <sub>1</sub>		Category C <sub>0</sub>	
		jacks	adults	jacks	adults	jacks	adults	jacks	adults
1997	Rapid River H	0	33	0	34	2	36	0	19
	McCall H	7	87	7	91	9	102	5	74
	Dworshak	0	19	0	19	1	14	1	13
	Imnaha AP	12	25	12	25	8	26	3	19
	Lookingglass H	2	22	2	23	3	39	0	37
	Pahsimeroi H	0	19	0	19	0	8	1	9
1998	Rapid River H	9	239	11	257	11	91	8	53
	McCall H	54	262	59	272	27	94	19	53
	Dworshak H	16	110	19	132	9	119	22	139
	Imnaha AP	31	37	34	41	11	19	8	11
	Lookingglass H	2	49	2	55	1	18	0	7
1999	Rapid River H	14	231	17	379	15	228	9	155
	McCall H	27	182	52	325	29	196	35	166
	Dworshak H	4	57	4	107	5	163	5	108
	Imnaha AP	19	65	44	117	22	58	12	38
	Lookingglass H	2	40	4	45	4	95	3	28

### LGR-LGR SARs for transported and in-river migrating fish

The T<sub>lgr</sub> varied considerably between hatcheries in 1997 with LGR-LGR SARs (excluding jacks) ranging from 0.36% to 1.48% (Figure 3a, Table 5). In 1998, T<sub>lgr</sub> SARs also ranged considerably from 0.45%-2.9%, generally higher than the SARs for 1997 (Figure 3b, Table 5). The T<sub>lgr</sub> SARs for migration year 1999 were the highest of the three years and ranged from 0.77% to 3.82% (Figure 3c, Table 5). Lookingglass hatchery always produced the lowest T<sub>lgr</sub> SARs and McCall hatchery always produced the highest SARs during the three years of the study. The mean T<sub>lgr</sub> LGR-LGR SAR for all hatchery stocks was 0.85%, 1.47%, and 2.37% for 1997, 1998, and 1999, respectively. The width of the confidence intervals ranged from as low as 12% of the estimate to as high as 45% of the estimate (Figure 3, Appendix Tables B-5 to B-7).

In Tables 5, 8 and 9, we are using the geometric mean as a measure of central tendency across years because Peterman (1981) showed that the distribution of SARs across years tend to be lognormally distributed. To estimate the average SAR across the different hatcheries, we are using an arithmetic mean because we do not expect this to be lognormally distributed. We could not accurately test the shape of the distribution with six hatcheries. A weighted average may also be useful to estimate the average SAR for the total hatchery production, since some hatcheries have higher production and would have more of an influence on the mean SAR (see Appendix F Response #12 on creation of annual weighted average SARs).

The LGR-LGR SARs for the T<sub>0</sub> group exhibited similar variability and patterns between hatcheries and years as the observed for the T<sub>lgr</sub> group although nearly all estimates were lower in the T<sub>0</sub> group (Figure 3a, Table 5). The mean T<sub>0</sub> LGR-LGR SAR for all hatchery stocks for the T<sub>0</sub> transported group was 0.77%, 1.11%, and 1.89% for 1997, 1998, and 1999, respectively (Figure 3, Table 5). Confidence intervals have not been formally estimated for the T<sub>0</sub> group; however, confidence intervals have been determined for the non-weighted estimate of T<sub>0</sub> (T<sub>0</sub>') and were

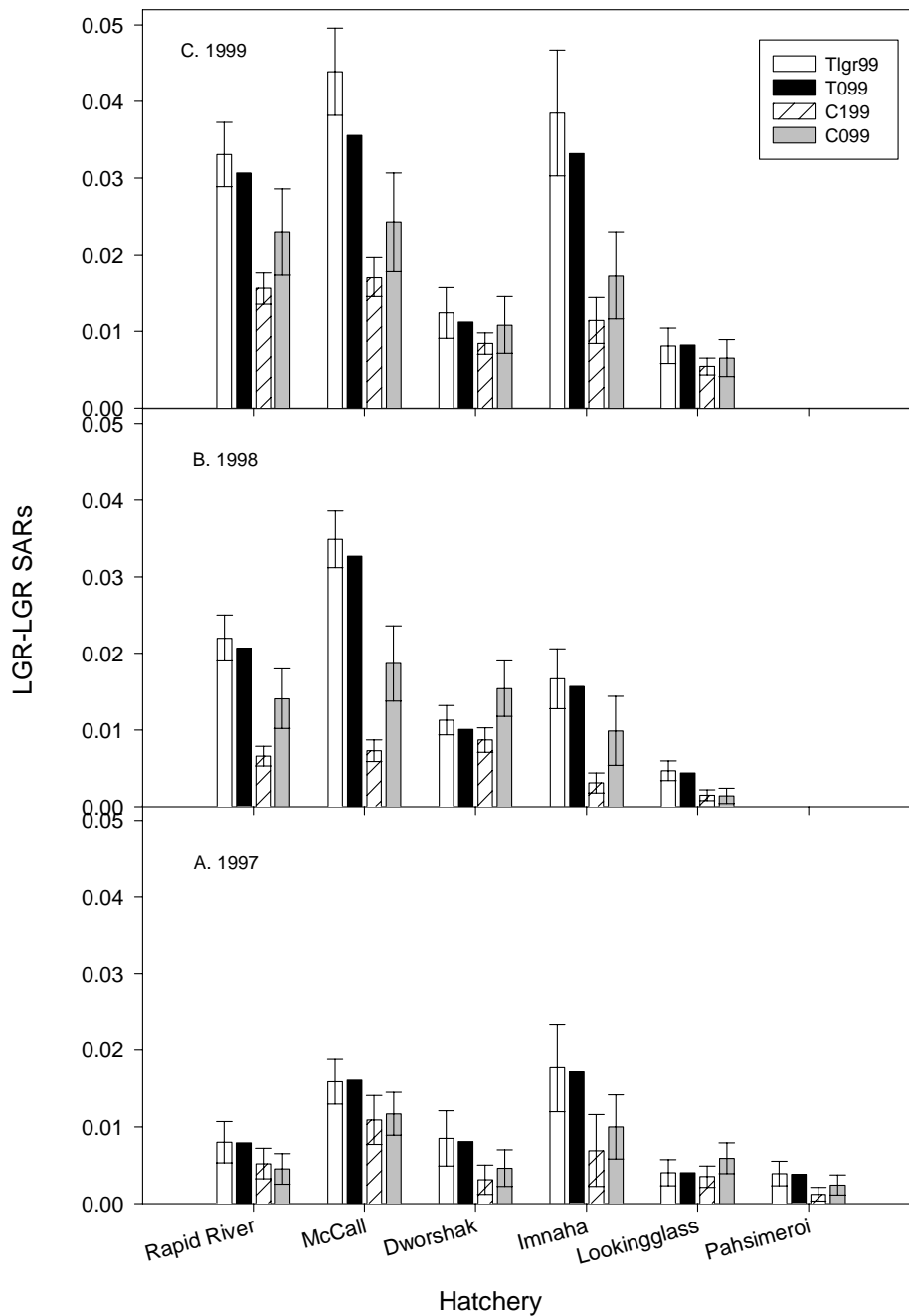


Figure 3. The LGR-LGR SAR (%) for the hatchery fish transported at LGR evaluated in the CSS studied.  $T_{lgr}$  refers to the fish transported from LGR,  $T_0$  refers to smolts transported at all projects upon first detection (weighted by the proportion actually transported),  $C_1$  refers to smolt that migrate in-river and have been detected at one or more Snake River detection sites,  $C_0$  refers to smolt that migrated in-river and never detected above MCN. Error bars represent 95% confidence intervals.

Table 5. The LGR-LGR SAR for the different transport and in-river groups.  $T_{lgr}$  refers to the fish transported from LGR,  $T_0$  refers to smolts transported at all projects upon first detection (weighted by the proportion actually transported),  $C_1$  refers to smolt that migrated in-river and have been detected at one or more Snake River detection sites,  $C_0$  refers to smolt that migrated in-river and were never detected above MCN.

Year	Hatchery	$T_{lgr}$	$T_0$	$C_1$	$C_0$
1997	Rapid River	0.80%	0.81%	0.52%	0.45%
	McCall	1.48%	1.89%	1.09%	1.09%
	Dworshak	0.85%	0.51%	0.31%	0.43%
	Imnaha AP	1.20%	0.73%	0.69%	0.86%
	Lookingglass	0.36%	0.41%	0.35%	0.58%
	Pahsimeroi	0.39%	0.27%	0.12%	0.21%
	Mean	0.85%	0.77%	0.51%	0.60%
1998	Rapid River	2.12%	1.68%	0.66%	1.23%
	McCall	2.90%	1.92%	0.73%	1.38%
	Dworshak	0.99%	0.71%	0.87%	1.32%
	Imnaha AP	0.91%	0.69%	0.31%	0.57%
	Lookingglass	0.45%	0.53%	0.15%	0.14%
	Mean	1.47%	1.10%	0.54%	0.93%
1999	Rapid River	3.12%	2.62%	1.56%	2.17%
	McCall	3.82%	2.93%	1.71%	2.00%
	Dworshak	1.16%	0.98%	0.84%	1.03%
	Imnaha AP	2.98%	2.28%	1.14%	1.32%
	Lookingglass	0.77%	0.66%	0.54%	0.59%
	Mean	2.37%	1.89%	1.16%	1.42%
1997-1999 Geometric mean	Rapid River	1.74%	1.53%	0.81%	1.07%
	McCall	2.54%	2.20%	1.11%	1.45%
	Dworshak	0.99%	0.71%	0.61%	0.84%
	Imnaha AP	1.48%	1.05%	0.62%	0.87%
	Lookingglass	0.50%	0.52%	0.30%	0.36%
	Pahsimeroi	0.39%	0.27%	0.12%	0.21%
	Mean	1.27%	1.05%	0.60%	0.80%

very similar to the confidence intervals surrounding the  $T_{lgr}$  estimates. Therefore, confidence intervals surrounding the weighted  $T_0$  group are likely similar to the  $T_{lgr}$  confidence intervals.

The  $C_1$  exhibited similar patterns in SARs between hatcheries and years as the  $T_{lgr}$  and  $T_0$  SARs, and like the transport groups, the highest SARs were observed from McCall hatchery fish and the lowest often occurred from Lookingglass hatchery (Figure 3, Table 5). The mean hatchery  $C_1$  LGR-LGR SAR was 0.51%, 0.54%, and 1.16% in 1997, 1998, and 1999, respectively (Table 5). The confidence intervals ranged from as low as 14% to a high of 71% of the estimate (Figure 3, Appendix Tables B-5 to B-7).

The LGR-LGR SARs  $C_0$  also demonstrated similar patterns between hatcheries and years as the  $T_{lgr}$ ,  $T_0$ , and  $C_1$  groups (Figure 3, Table 5). The mean hatchery  $C_0$  LGR-LGR SAR was 0.60%, 0.93%, 1.40% for 1997, 1998, and 1999, respectively (Table 5). The confidence intervals ranged from as low as 26% to a high of 79% of the estimate (Figure 3, Appendix Table B-5).

The LGR-LGR SAR for wild fish was only calculated for the T<sub>0</sub> and the C<sub>0</sub> groups. The wild T<sub>0</sub> LGR-LGR SAR ranged from a low of 0.30% in 1995 and a high of 1.08% in 1999 (1999 SARs will likely increase as age 5 fish return next year) (Table 6). The C<sub>0</sub> LGR-LGR SAR ranged from a low of 0.27% in 1996 (1995 was similar with 0.35%) and a high of 1.93% in 1999 (Table 6).

Table 6. The LGR-LGR and BON-LGR SARs for the different transport and in-river groups of wild fish. T<sub>0</sub> refers to smolt transported at all projects upon first detection (weighted by the proportion actually transported), C<sub>0</sub> refers to smolts that migrated in-river and were never detected above MCN (see exception for 1994).

Year	LGR-LGR SAR		BON-LGR SAR	
	T <sub>0</sub>	C <sub>0</sub>	T <sub>0</sub>	C <sub>0</sub>
1994	0.49%	0.15%	0.50%	0.52%
1995	0.30%	0.35%	0.31%	0.76%
1996	0.40%	0.27%	0.41%	0.78%
1997	1.71%	1.76%	1.75%	3.64%
1998	1.12%	1.29%	1.14%	2.12%
1999	1.88%	1.93%	1.92%	3.01%
1994-1999*	0.77%	0.63%	0.79%	1.39%
1995-1999*	0.85%	0.84%	0.86%	1.69%

\* geometric mean

In 1997 the SARs for both the T<sub>0</sub> and the C<sub>0</sub> groups were substantially higher than all the comparable hatchery groups. The average wild SAR for the T<sub>0</sub> group was 122% higher than the average of all hatcheries in 1997 (Table 7). In 1998 and 1999 the average wild and hatchery T<sub>0</sub> groups were nearly identical (Table 7); however some individual hatcheries were substantially higher and lower than the wild fish. The wild C<sub>0</sub> LGR-LGR SARs were 191%, 39%, and 36% greater than the average C<sub>0</sub> hatchery groups in 1997, 1998, and 1999, respectively (Table 7).

Table 7. The percent difference<sup>1</sup> in LGR-LGR and BON-LGR SARs, T/I ratios and D values observed for wild fish relative to hatchery fish between 1997-1999. T<sub>0</sub> refers to smolt transported at all projects upon first detection (weighted by the proportion actually transported), C<sub>0</sub> refers to smolt that migrated in-river and never detected above MCN dam.

Year	SAR T <sub>0</sub>		SAR C <sub>0</sub>		T <sub>0</sub> /C <sub>0</sub>	D (T <sub>0</sub> )
	LGR-LGR	BON-LGR	LGR-LGR	BON-LGR		
1997	121.96%	121.96%	190.93%	125.95%	-18.04%	6.51%
1998	1.16%	1.16%	38.91%	19.90%	-36.41%	-23.82%
1999	-0.69%	-0.69%	35.78%	42.55%	-23.12%	-23.52%

<sup>1</sup> The percent difference of wild fish relative to hatchery fish is expressed as  $(\theta_{\text{wild}}/\theta_{\text{hatchery}} - 1) * 100\%$  where  $\theta$  represents the variable of interest such as SAR, T/C, or D.

### BON-LGR SARs for transported and in-river migrating fish

The BON-LGR SARs for the T<sub>igr</sub>, T<sub>0</sub>, and C<sub>0</sub> hatchery groups showed the same yearly patterns as the LGR-LGR SARs with 1997 lower than 1998, which was lower than the 1999 SARs (Table 8). The variability of SARs within years between hatcheries was high for the T<sub>igr</sub>, T<sub>0</sub>, and C<sub>0</sub> groups.

The  $T_0$  BON-LGR SARs for wild fish ranged from a low 0.31% in 1995 to a high of 1.92% in 1999 (likely to increase as age 5 fish return next year), with a geometric mean of 0.86% (Table 6). The  $C_0$  BON-LGR SARs also demonstrated large interannual variability, but the low and high estimates occurred on different years. For wild fish  $C_0$  BON-LGR SARs ranged from a low 0.52% in 1994 to a high of 3.64% in 1997, with a geometric mean of 1.69% (Table 6).

The difference between the average hatchery and wild yearly BON-LGR SARs for the  $T_0$  groups were identical to the differences between the LGR-LGR SARs, because the latter SARs are simply divided by a constant 0.98 survival rate to derive the former SARs for both hatchery and wild fish. The wild  $C_0$  BON-LGR SARs were again higher than the average hatchery SARs, with wild SARs 126%, 20%, and 43% higher in 1997, 1998, and 1999, respectively (Table 7).

Table 8. The BON-LGR SAR for the different transport and in-river hatchery groups.  $T_{lgr}$  refers to the fish transported from LGR,  $T_0$  refers to smolts transported at all projects upon first detection (weighted by the proportion actually transported),  $C_0$  refers to smolts that migrated in-river and never detected above MCN.

Year	Hatchery	$T_{lgr}$	$T_0$	$C_0$
1997	Rapid River	0.81%	0.82%	1.37%
	McCall	1.51%	1.93%	2.03%
	Dworshak	0.87%	0.52%	1.58%
	Imnaha AP	1.22%	0.75%	2.74%
	Lookingglass	0.37%	0.42%	1.44%
	Pahsimeroi	0.40%	0.27%	0.49%
	Mean	0.86%	0.79%	1.61%
1998	Rapid River	2.16%	1.71%	2.11%
	McCall	2.96%	1.97%	2.51%
	Dworshak	1.01%	0.73%	2.81%
	Imnaha AP	0.93%	0.71%	1.08%
	Lookingglass	0.46%	0.54%	0.33%
	Mean	1.50%	1.23%	2.08%
1999	Rapid River	3.18%	2.67%	3.07%
	McCall	3.90%	2.98%	2.54%
	Dworshak	1.18%	1.00%	1.81%
	Imnaha AP	3.04%	2.33%	2.06%
	Lookingglass	0.79%	0.68%	1.07%
	Mean	2.42%	1.80%	2.11%
1997-1999 Geometric mean	Rapid River	1.78%	1.56%	2.07%
	McCall	2.59%	2.25%	2.35%
	Dworshak	1.01%	0.72%	2.01%
	Imnaha AP	1.51%	1.07%	1.83%
	Lookingglass	0.51%	0.53%	0.79%
	Pahsimeroi	0.40%	0.27%	0.49%
	Mean	1.30%	1.07%	1.59%

## Ratios of SARs

### $T_{lgr}/T_0$ ratios

The LGR-LGR SAR for the  $T_{lgr}$  group was higher than the  $T_0$  group in a majority of the cases across hatcheries for each year, signified by a  $T_{lgr}/T_0$  greater than 1.0 (Figure 3, Table 9). The overall geometric mean  $T_{lgr}/T_0=1.24$ . While the  $T_{lgr}$  LGR-LGR SAR was consistently greater than the  $T_0$ , the  $T_{lgr}$  confidence intervals overlapped the  $T_0$  point estimate in every case (Figure 3, Appendix Tables B-9 to B-11).

Table 9. The ratios of SARs for the different transport and in-river hatchery groups.  $T_{lgr}$  refers to the fish transported from LGR,  $T_0$  refers to smolts transported at all projects upon first detection (weighted by the proportion actually transported),  $C_1$  refers to smolts that migrate in-river and have been detected at one or more detection sites,  $C_0$  refers to smolts that migrated in-river and never detected above MCN dam. All ratios are the LGR-LGR SARs except for the D value. The value of D is the ratio of the transport BON-LGR SAR to the control (in-river) BON-LGR SAR.

Year	Hatchery	$T_{lgr}/T_0$	$C_1/C_0$	$T_{lgr}/C_0$	$T_0/C_0$	$D(T_{lgr})$	$D(T_0)$
1997	Rapid River	0.986	1.143	1.753	1.777	0.593	0.601
	McCall	0.785	0.996	1.356	1.727	0.745	0.949
	Dworshak	1.672	0.726	1.991	1.184	0.547	0.327
	Imnaha AP	1.628	0.806	1.400	0.856	0.446	0.274
	Lookingglass	0.891	0.601	0.626	0.703	0.258	0.289
	Pahsimeroi	1.450	0.559	1.821	1.251	0.814	0.562
	Geometric mean	1.182	0.779	1.401	1.183	0.532	0.450
1998	Rapid River	1.263	0.538	1.727	1.367	1.024	0.811
	McCall	1.504	0.528	2.095	1.392	1.178	0.783
	Dworshak	1.382	0.658	0.748	0.539	0.359	0.260
	Imnaha AP	1.316	0.540	1.587	1.206	0.859	0.653
	Lookingglass	0.861	1.090	3.285	3.817	1.419	1.649
	Geometric mean	1.244	0.643	1.698	1.364	0.880	0.663
	Geometric mean	1.244	0.643	1.698	1.364	0.880	0.663
1999	Rapid River	1.192	0.720	1.440	1.208	1.036	0.869
	McCall	1.307	0.854	1.910	1.461	1.535	1.174
	Dworshak	1.182	0.814	1.119	0.947	0.650	0.550
	Imnaha AP	1.306	0.863	2.256	1.728	1.474	1.129
	Lookingglass	1.167	0.921	1.320	1.131	0.741	0.635
	Geometric mean	1.229	0.832	1.558	1.267	1.024	0.775
	Geometric mean	1.229	0.832	1.558	1.267	1.024	0.775
1997-1999 Geometric mean	Rapid River	1.141	0.762	1.634	1.432	0.857	0.751
	McCall	1.155	0.766	1.757	1.520	1.104	0.956
	Dworshak	1.398	0.730	1.186	0.845	0.503	0.360
	Imnaha AP	1.409	0.721	1.711	1.213	0.827	0.587
	Lookingglass	0.964	0.845	1.395	1.447	0.647	0.671
	Pahsimeroi	1.450	0.559	1.821	1.251	0.814	0.562
	Geometric mean	1.240	0.725	1.567	1.262	0.769	0.621

### $C_1/C_0$ ratios

Across all hatcheries each year, the LGR-LGR SAR for the  $C_0$  group was higher than the  $C_1$  group in 14 out of 16 cases, also signified by a  $C_1/C_0$  ratio less than 1.0 (Figure 3, Table 9). The

overall geometric mean  $C_1/C_0$  ratio was 0.725. Although this pattern was consistent, the confidence intervals overlapped in 11 of 16 cases (Figure 3, Appendix Tables B-9 to B-11).

### ***T/I ratios***

The median ratios of LGR-LGR SARs for  $T_{lgr}$  to  $C_0$  exceeded 1.0 for each hatchery stock and migration year except Lookingglass hatchery chinook in migration year 1997 and Dworshak hatchery chinook in migration year 1998 (Table 9). The overall geometric mean  $T_{lgr}/C_0$  ratio was 1.567. The  $T_0/C_0$  ratio also exceeded 1.0 except in the above cases and in Imnaha in migration year 1997. Lookingglass hatchery exhibited the highest and lowest  $T_0/C_0$  across all hatcheries during the 3 yrs of this study with 1997  $T_0/C_0$  of 0.703 and a  $T_0/C_0$  of 3.817 in 1998 (Table 9). In general, the  $T_0/C_0$  was less than 1.5 across all hatcheries and years, and  $T_0/C_0$  averaged across hatcheries was 1.183, 1.364, and 1.267 in 1997, 1998, and 1999, respectively (Table 9). The overall geometric mean  $T_0/C_0$  ratio was 1.262.

The  $T_0/C_0$  for wild fish was less than 1.0 in 4 out of the 6 yrs analyzed (Table 10). In 1994, the  $T_0/C_0$  was 3.189, over twice the value of the next highest  $T_0/C_0$  of 1.489 observed in 1996 (Table 10). Overall, transportation demonstrated a slight benefit to the survival from LGR-LGR with the geometric mean value of  $T_0/C_0$  for 1994-1999 equal to 1.226; however, this benefit was largely influenced by 1994. When 1994 was not averaged into the overall  $T_0/C_0$ , the transport benefits were no longer observed as  $T_0/C_0$  was approximately 1.0 (Table 10). The  $T_0/C_0$  for wild fish was 18-36% lower than the  $T_0/C_0$  observed for hatchery fish between 1997 and 1999 (Table 7).

Table 10. The T/I ratios and the ‘D’ for the  $T_0$  groups and  $C_0$  groups of wild fish between 1994-1999, with the geometric mean of 1994-1999 and 1995-1999.

Year	$T_0/C_0$	D
1994	3.189	0.958
1995	0.867	0.403
1996	1.489	0.526
1997	0.975	0.480
1998	0.868	0.538
1999	0.974	0.637
1994-1999	1.226	0.568
1995-1999	1.012	0.511

### ***‘D’ values***

The  $BON-LGR\ SAR_{T_{lgr}} / BON-LGR\ SAR_{C_0}$  values (or ‘D’ value) for hatchery fish were generally less than 1.0 estimated using either the  $T_{lgr}$  or the  $T_0$  groups. ‘D’ values were much less than 1.0 in 1997 with values ranging from 0.258 for Lookingglass hatchery fish to 0.814 for Pahsimeroi hatchery fish (Table 9). In 1999, several of the D values were greater than 1.0 and 1998 was intermediate to 1997-1999. In 1997, 1998, and 1999 the geometric mean ‘D’ value was 0.532, 0.880, and 1.024, respectively, estimated with the  $T_{lgr}$  group. The ‘D’ values for the  $T_0$  were, in most cases, lower than the ‘D’ values observed for the  $T_{lgr}$  group across all hatcheries and years (Table 9). In 1997, 1998, and 1999 the geometric mean ‘D’ value was 0.450, 0.663, and 0.775, respectively, estimated with the  $T_0$  group with values ranging from 0.260 to 1.649 between hatcheries over this time period (Table 9). The geometric mean ‘D’ value for all years and all hatcheries was 0.769 and 0.621 for  $T_{lgr}$  and  $T_0$  groups, respectively (Table 9).

D values for wild spring/summer chinook were consistently and often considerably lower than 1.0 indicating that survival after transported fish are released below BON was less than the post-BON survival of fish that migrated through the hydrosystem. The 1994 D value was over 50% greater than the next highest D value (observed in 1999; Table 10). The geometric mean D value for all years including and excluding 1994 suggests that this post-hydrosystem survival is nearly twice as high for in-river fish as for transported fish (Table 10).

The 1997 'D' value for wild fish was similar to the mean 'D' value for all hatcheries, whereas the 1998 and 1999 the 'D' values for the wild fish were nearly 30% lower than the hatchery stocks (Table 7).

## DISCUSSION

In this study we have estimated over different life stages for Snake River spring/summer chinook (in-river survivals, LGR-LGR and BON-LGR SARs, and the ratios of these SARs, for both hatchery and wild fish that were transported-estimated from LGR only and from all transport projects- or migrated in-river- undetected or detected at least one or more times. Comparison of this information can provide much insight into the performance of these stocks under alternative management actions. Under CSS, an important comparison is between hatchery and wild fish. Ultimately, the region will develop long-term management actions aimed at recovering and rebuilding wild salmon. Thus, wild fish are the context. However, in some years wild fish abundance is so low that it is not feasible to tag enough smolts to reliably estimate survival over the different life stages. Hatchery fish, however, are very abundant and sufficient numbers can be tagged to obtain high statistical power. Thus, if hatchery fish are good surrogates to wild fish (either in absolute or relative terms) then the performance of hatchery fish may be a more precise measure of the performance of wild fish. We compared in-river survival rates, and different SARs and their ratios between hatchery and wild fish over the 3 yrs of the CSS of study. Relative performance of hatchery and wild fish in 1997 was considerably different than in 1998 and 1999; however, in 1997 very few wild fish were PIT-tagged, and thus these estimates may be unreliable. Given that only 3 yrs of comparisons are possible between hatchery and wild fish, conclusions and relationships between hatchery and wild fish are premature.

Estimating survival rates for Snake River spring/summer chinook over different life stages that are experiencing different management actions (transportation versus in-river migration) aimed at mitigation provides information to two obvious questions: 1) Are current management actions mitigating for the impacts of the hydrosystem as measured by these survival rates? 2) Does transportation provide a significant benefit over migrating through the hydrosystem? Within the latter question we can focus on why and where transportation benefits may or may not occur. Because there is little argument that survival rates through the hydrosystem are greater for transported fish than fish that migrate in-river, the arguments logically should address the presence of delayed mortality attributed to each specific experience. Related to these to questions are how alternative experiences ( $T_{igr}$  versus  $T_0$  or  $C_1$  versus  $C_0$ ) for transported and in-river fish affect survival rates over different life stages.

In this paper, we have estimated the LGR-LGR SAR survival rates, which partially describes the direct (occurring within the hydrosystem) and delayed impacts of the hydrosystem on survival over this life stage. Prior to the completion of the dams and based on analytical evaluations, the SARs that Snake River spring/summer chinook should experience in order to recover the populations is between 2-6%. In this paper, current estimates of SARs averaged across year for in-river migrants and transported fish range from 0.8%-1.3%, and 0.84%-0.85%, for hatchery and

wild fish, respectively. This suggests that current management actions are not meeting this minimum survival rate to recover Snake River populations.

Because a majority of the fish are transported at survival rates near 100%, current survival through the hydrosystem is undoubtedly higher than it was historically when no dams existed on the Snake River. Thus, if the decrease in LGR-LGR SARs, which occurred after 1975 when the last Snake River dam was completed, are indeed a result of the hydrosystem then arguments should focus on delayed hydrosystem mortality to explain why current management actions cannot achieve the necessary survival improvements. Other hypotheses have been put forth that are unrelated to the hydrosystem to explain the decrease in survival after smolts have migrated past the hydrosystem (Marmorek and Peters, 1998).

One argument that could be made to explain historic and current SAR differences is that ocean productivity changed after 1975 and can no longer support salmon populations rivaling historic levels (Mantua et al. 1997, Welch et al. 2000). In order to address this question, comparisons have been made between Snake River spring/summer chinook that must negotiate 8 dams when migrating through the hydrosystem to spring/summer chinook lower in the Columbia River that migrate through only 1-3 dams (Marmorek and Peters 1996, Schaller et al. 1999, 2000). This analysis suggests that indeed ocean productivity did change after 1975 as both upstream and downstream stocks exhibited declines. However, upstream stocks exhibited a much more severe decline suggesting, that unless shared ocean conditions are worse for upstream stocks than downstream stocks, the greater decline of the upstream stocks was likely a result of completion of the hydrosystem (Marmorek and Peters 1996). In addition, the additional direct mortality experienced by upstream stocks migrating through more dams and reservoirs could not explain these differences. Therefore, the increase of delayed hydrosystem mortality for upstream stocks resulting from migrating through 8 hydroelectric dams and reservoir is a likely partial explanation for the difference between upstream and downstream stock performance (Deriso et al. 1996). Comparison of upstream to downstream stock performance is a major objective of the CSS. At the time this report was completed, too few broods have returned from downstream stocks to make these comparisons, and whether hatchery stocks are good surrogates for wild fish is unknown.

We have estimated LGR-LGR SARs for both fish that were transported and fish that migrated in-river, the major dichotomy of a smolt's route through the hydrosystem. As stated above the SARs through either of these routes of passage are not sufficient to recover listed Snake River spring/summer chinook stocks. Estimating the SARs for each of these routes of passage allows us to compare the effectiveness of the major current management action, transportation, to migrating through the hydrosystem. The easiest way to make this comparison is to calculate the  $T_0/C_0$  ratio. If the T/I ratio is much greater than 1.0 then transportation can provide a significant benefit to the population (relative to current hydrosystem configuration and operation); not necessarily a sufficient benefit (Mundy et al. 1994). The confidence intervals around the T/I ratio in the majority of hatcheries for each year encompassed 1.0, suggesting that this benefit is not significant. However, because T/I was greater than 1.0 in 14 out of 16 comparisons (3 yrs x 5 (6 in 1997) hatcheries) suggests that T/I is likely greater than one but cannot be detected due to low statistical power. But the transportation benefit is modest at best as the average T/I ratio across hatcheries was between 1.2 and 1.3 between 1997 and 1999. For wild fish, the T/I ratio suggest that there is little to no benefit to being transportation as T/I ratios averaged 1.2 between 1994-1999, with the 1994 T/I ratio twice the next highest T/I ratio being very influential (i.e. T/I=1.0 averaged between 1995-1999). As T/I was lower than 1.0 in 4 of the 6 yrs analyzed, it is possible that transport provides no benefit or may even be detrimental to wild stocks in most years. Given the small sample size relative to hatchery fish, the confidence intervals around these estimates are

likely large and thus significance differences between LGR-LGR SARs of transported wild fish and in-river wild migrants estimates are unlikely.

There is little argument that the survival rate of smolts during transportation is higher than while migrating through the hydrosystem. Therefore, in order for transported fish to have similar LGR-LGR SARs as in-river fish the delayed mortality of transported fish must be higher. This is corroborated by the lower BON-LGR SARs observed for transported fish than for in-river migrants. Like the T/I ratio, the easiest way to compare BON-LGR SARs is take the ratio, known as 'D'. A 'D' less than 1.0 suggests that the BON-LGR SAR is lower for fish that have been transported. In this study, the D ( $T_0$ ) value for hatchery fish was less, often much less, than 1.0 in 14 out of 16 cases. The average D value for all hatcheries for all years was 0.61. For wild fish, D was also less than 1.0 between 1994 and 1999. This study suggests that the post-BON survival of wild smolts that were transported was approximately half that of smolts that were allowed to migrate through the hydrosystem. This estimate of 'D' is considerably lower than the 'D'=0.7 assumed in the analyses used in the NMFS BiOp to develop the RPA for salmon recovery. Overestimation of 'D' results in an overestimate of the benefit to the Snake River spring/summer chinook population because a majority of these fish are transported.

Within the two major routes of passage through the hydrosystem (transport or in-river), comparisons in SARs between different routes of passage ( $T_{lgr}/T_0$  and  $C_1/C_0$ ) also provide evidence for the presence of delayed hydrosystem mortality (Budy et al. *in press*). We compared the LGR-LGR SARs of hatchery fish transported at LGR ( $T_{lgr}$ ) to hatchery fish transported from all transport projects ( $T_0$ ). In 12 out of 16 cases the  $T_{lgr}$  SAR was greater than the  $T_0$  SAR. Again, this was not significant but given the high frequency in which  $T_{lgr}/T_0$  was greater than 1.0 suggests that statistical power was too low for a detection of true differences. The lower  $T_0$  may simply be a result of mortality that occurs while migrating to the lower transport projects. If true, evaluation of  $T_0$  without converting smolts transported at lower projects to LGR equivalents, should result in a  $T_{lgr}/T_0$  roughly equal to 1.0. After making this adjustment, the  $T_{lgr}/T_0$  was still greater than 1.0 in 12 out of 16 cases suggesting that differences in-river survival cannot explain the lower SAR for  $T_0$  but rather differences in the ability to survive after fish are released from the barges or trucks. Therefore, the stress and resulting mortality of migrating through one or more projects and then being transported may be greater than the stress and resulting mortality of just being transported, corroborated by the lower BON-LGR SAR for the  $T_0$  group.

A similar comparison can be made with smolts that have to migrate through the hydrosystem. Some smolts may migrate through the transport projects either over spillways or through the turbines and thus, will not be detected. In this study, we compared the SARs of hatchery fish detected at one more transport projects ( $C_1$ ) to the SARs of hatchery fish not detected ( $C_0$ ). Again, in 12 out of 16 cases the  $C_1/C_0$  ratio was less than 1.0, with 5 of the cases being significant. Sandford and Smith (2001) also observed this difference between wild fish with  $C_1$  and  $C_0$  detection histories. Difference in survival through the hydrosystem cannot explain these difference because the average survival of the  $C_1$  fish (98% survival through the bypass facility) should be higher than the average survival of the  $C_0$  fish (average of 98% survival through spillway and 90% survival through the turbines). Thus, the lower LGR-LGR SARs for  $C_1$  fish must be explained by the difference in delayed hydrosystem mortality.

A result of  $C_1/C_0 < 1.0$  is highly pertinent to past discussions as to what constitutes a true in-river "control". In many studies, when evaluating the effectiveness of the transportation program any smolt migrating through the hydrosystem regardless of their detection history was considered a control fish. Indeed, before the invention of PIT-tags it was not possible to discern fish with different in-river migration detection histories. However, the collection facilities at LGR, LGS,

LMN, and MCN were developed to collect fish for transportation. With the transportation program, untagged fish are not generally passed through the collection facilities and then returned to the river. Therefore, the detection history that best represents what a smolt migrating through the hydrosystem actually experiences with the transportation program in place (thus the use of term “control” fish) would be a never detected (at the transport projects) detection history. Results from this study suggest that including all detection histories of an in-river migrant would overestimate the T/I ratio and the benefit of the transportation program.

While hydrosystem delayed mortality may have an empirical basis, what is important in terms of ‘D’ is why this mortality is greater for transported fish than for non-transported fish (i.e. ‘D’ < 1). Because C<sub>1</sub> fish have lower SARs than C<sub>0</sub> fish not explained by direct mortality in the hydrosystem, it is apparent that the collection facilities, which all transported fish must pass through, are stressful to smolts. In addition, transported smolts are subjected to the stress of crowding and mixing with larger steelhead smolts, and injury during transport. High levels of descaling have been reported for transported smolts (Williams and Mathews 1995; Basham and Garrett 1996). Stress, injury, and crowding may trigger disease outbreak (e.g., BKD, fungal infection) and lead to delayed mortality. The physiological state and time of saltwater entry may also be poorly synchronized for transported groups. For example, Fagurlund et al. (1995) cite studies of effects of premature saltwater entry (incomplete smoltification) with coho salmon, resulting in high mortality, and, in many of the survivors, a reduction in or cessation of growth. These factors may be responsible for the higher delayed mortality experience by transported fish as suggested by a ‘D’ value consistently less than 1.

While the theoretical mechanisms that may result in delayed hydrosystem mortality that is greater for transported fish than fish allowed to migrate in-river appear to be supported by empirical evidence based on PIT-tag information, it is possible that the PIT-tag information is misleading. First, we have not included the variance around these point estimates. Currently, we are developing a bootstrapping method to provide the appropriate confidence intervals around our estimates. Because SARs are so low, the small sample of adults will likely result in very large variance around the SAR estimates. However, observing a  $D < 1.0$  6 of 6 years evaluated for wild fish and in 13 of 16 cases evaluated for hatchery fish suggests that delayed hydrosystem mortality is greater for transported fish than in-river fish. Second, nearly all the wild PIT-tagged smolts that were transported, passed through the sampling facility and may have been subject to additional stress that the non-tagged transported smolts did not experienced. Given this past treatment of PIT-tagged transported wild fish, we may not be accurately representing how the non-tagged transported population was treated. It is worth noting that transported SAR for wild fish was greater or equal to the SAR for transported hatchery fish that for the most part were not subject to the sampling facilities. The lower T/I and D values observed for wild fish relative to hatchery fish is a result of higher SARs of in-river wild fish rather than a decreased SAR of transported wild fish. Because accurate estimates of LGR-LGR and BON-LGR SARs for transported fish are the most important critical uncertainties in determining the management action most effective at recovering listed Snake River spring/summer chinook, we are now carefully designing how PIT-tagged smolts are used to represent current impacts of the hydrosystem to actual population.

This study provides empirical evidence for delayed hydrosystem mortality for both hatchery and wild Snake River spring/summer chinook. However, this evidence primarily describes the relative impacts of different routes of passage on delayed mortality. Many lines of evidence suggest that both fish that were transported and detected in-river migrants exhibited delayed mortality from their experience, but non-detected smolts (C<sub>0</sub> has the highest BON-LGR SARs) also likely experience delayed hydrosystem mortality. Stress has been demonstrated to be

cumulative (e.g., Adams, et al., 1985; Bjornn et al., 1984-87; Vaughn et al., 1984; Wedemeyer et al., 1990; and Submission 20 of Marmorek and Peters, 1998), and injury, trauma, and stress has been demonstrated to be a result from passage through a dam and a reservoir (Dawley and Ebel 1975; Dawley et al. 1975; Wright and McLean 1985; Krise et. al. 1990, Williams and Mathews 1995; Hetherman et al. 1998; Coutant 1999; FPC 2000; Mesa et al. 2000). Therefore, passage through 8 hydroelectric dams and reservoirs is likely to cause severe stress that would affect the survival of a smolt after migrating through hydrosystem (Budy et al, *in press*).

The estimate of SARs for different route of passage through the hydrosystem is crucial in defining the management options to recover Snake River stocks. If the benefits of transportation are lower than assumed for analyses defining the near term effects of the current management action (NMFS 2000) then this option, which is highly dependent on transportation, is less likely to lead to recovery of Snake River stocks. Explicitly including 'D' and delayed hydrosystem mortality into analyses that evaluate the benefit of alternative management scenarios would identify actions that can reduce these sources of mortality as most likely to recover these stocks. This conclusion shifts the emphasis from status quo recovery efforts to alternative efforts.

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## **Appendix A**

**PIT tag releases for Snake River  
spring/summer wild and hatchery chinook**

**Table A-1. Wild yearling spring/summer chinook releases above Lower Granite Dam (release site names are found in 2001 PIT Tag Specification Document, PSMFC 3/6/2001)**

region	release site	Migration Year						
		1994	1995	1996	1997	1998	1999	Total
Clearwater R Basin								
clw	AMERR		696				839	1,535
clw	BRUSHC	2,554	126					2,680
clw	CFCTRP	1,992	2,862	371	577	1,287	3,136	10,225
clw	CLEARC	265	531	2		500	349	1,647
clw	CLWR			52	22	4		78
clw	CLWTRP	761	1,051					1,812
clw	CROOKC	34	192					226
clw	CROOKR	1,971	2,245	502			4	4,722
clw	CROTRP	2,030	3,468	191	1	478	746	6,914
clw	KOOS			8				8
clw	LOLOC	2,061	2,324	184		854	2,438	7,861
clw	MEADOC		108	219		61	583	971
clw	NEWSOC	60	936			28	2,022	3,046
clw	PAPOOC		290				833	1,123
clw	PETEKC						300	300
clw	REDR	1,211	642				89	1,942
clw	REDTRP	169	2,659	783	94	1,710	1,641	7,056
clw	SQUAWC						173	173
clw	WHITCC		83					83
clw	WHITSC						337	337
Clearwater R Basin: subtotal		13,108	18,213	2,312	694	4,922	13,490	52,739
Grande Ronde R Basin								
grn	CATHEC	1,000	2,333	1,684	1,257	2,153	2,156	10,583
grn	GRANDR	3,348	3,330	402	82	1,959	2,923	12,044
grn	LOOKGC	2,315	3,868	2,034	14	2,086	3,173	13,490
grn	LOSTIR	725	1,002	977	1,920	1,488	2,101	8,213
grn	MINAMR	997	996	998	589	998	1,006	5,584
grn	WALLOR						45	45
grn	WENR	212	259	170				641
grn	WENRSF	786	740	827	62			2,415
Grande Ronde R Basin: subtotal		9,383	12,528	7,092	3,924	8,684	11,404	53,015
Imnaha River Basin								
imn	IMNAHR	1,747	996	997	1,017	1,010	1,009	6,776
imn	IMNAHW	688		998		1,996	2,001	5,683
imn	IMNTRP	959	1,181	2,308	680	5,409	7,308	17,845
Imnaha River Basin: Subtotal		3,394	2,177	4,303	1,697	8,415	10,318	30,304
Mainstem Snake R at Lewiston Idaho:								
lew	SNKTRP	934	2,067	913		961	3,624	8,499

**Salmon River Basin**

sal	ALTULC		331					331
sal	BARGAC						1	1
sal	BEARVC		1,455			427	820	2,702
sal	BEAVEC		533					533
sal	BIGC	721	1,482				1,427	3,630
sal	CAMASC	215	1,528					1,743
sal	CAPEHC		1,442				270	1,712
sal	CHAMBC	76	241					317
sal	CHAMWF	496	916					1,412
sal	ELKC	964	1,512			246	700	3,422
sal	FRENCC	376	593	500				1,469
sal	HERDC	119	534				959	1,612
sal	HUCKLC		258					258
sal	JOHNSC	43	193	1			1,177	1,414
sal	JOHTRP						7,767	7,767
sal	KNOXB						2	2
sal	LAKEC	252	405	135	400	744	5,328	7,264
sal	LEMHIR				5	63	699	767
sal	LEMHIW	804	2,027	219	274	1,028	3,442	7,794
sal	LOONC	396	964				1,029	2,389
sal	LSFTRP					1,329	2,421	3,750
sal	MARSHC	971	1,575				769	3,315
sal	MARTRP	6,769	3,674	278		1,039	2,355	14,115
sal	PAHSIR	371	998					1,369
sal	PAHTRP	550	2,872	778	265	1,205	2,036	7,706
sal	PETTLC		189					189
sal	RUSHC	10	15				27	52
sal	SAEFSF						6	6
sal	SALEFW	219	1,393	134				1,746
sal	SALR	711	1,179	450				2,340
sal	SALREF	883	986					1,869
sal	SALRNF		520					520
sal	SALRSF	3,981	1,571	700	700	1,007	1,001	8,960
sal	SALTRP	2,913	3,937	1,425		1,416	3,628	13,319
sal	SAWTRP	334	1,760	800		339	631	3,864
sal	SECESR	422	1,549	571	260	1,277	3,225	7,304
sal	SFSTRP	3,348	2,680	1,297	1,779	2,178	3,804	15,086
sal	SMILEC	517	511					1,028
sal	STOLP					111	38	149
sal	SULFUC		728				443	1,171
sal	VALEYC	848	1,551				1,001	3,400
sal	WILLIC			89				89
sal	YANKWF		171			81	1,325	1,577
<b>Salmon River Basin: subtotal</b>		<b>27,309</b>	<b>42,273</b>	<b>7,377</b>	<b>3,683</b>	<b>12,490</b>	<b>46,331</b>	<b>139,463</b>
<b>Grand Total</b>		<b>54,128</b>	<b>77,258</b>	<b>21,997</b>	<b>9,998</b>	<b>35,472</b>	<b>85,167</b>	<b>284,020</b>

**Table A-2. Number of hatchery chinook smolts from the 1997 migration year PIT tagged and released from Snake River Basin hatcheries and lower Columbia River's Carson Hatchery for the Comparative Survival Study.**

**1997 PIT Tag Releases**

<b>Tagging Site (code)</b>	<b>Tagging Dates</b>	<b>Coord ID</b>	<b>Release Site (code)</b>	<b>Release Dates</b>	<b>Release Number</b>
Carson NFH (CARS)	2/3-2/5/97	LRB	Carson H, Wind R (CARS)	4/17/98	4,982
Dworshak NFH (DWOR)	2/5-2/13/97	HLB	Dworshak Hatchery (DWOR)	4/7/97	14,080
Kooskia NFH (KOOS)	1/29/97		Kooskia Hatchery (KOOS)	4/8/97	4,075
Sawtooth SFH (SAWT)	9/30-10/2/96	LRB	Pahsimeroi Hatchery (PAHP)	4/7/97	33,432
McCall SFH (MCCA)	3/4-3/8/97		SF Salmon R (Knox Br) (KNOXB)	3/20/97	52,653
Rapid River SFH (RAPH)	9/25-9/28/96		Rapid River Hatchery (RAPH)	Volitional release median 4/1/97	40,495
Lookingglass SFH (LOOH)	1/28-1/31/97	PMS	Imnaha R Weir (IMNAHW)	4/7/97	13,378
	2/3-2/13/97		Lookingglass Hatchery (LOOH)	4/7/97	40,027

Release date for Rapid River Hatchery for 1997 is estimated median date of 1-month volitional release.

**Table A-3. Number of hatchery chinook smolts from the 1998 migration year PIT tagged and released from Snake River Basin hatcheries and lower Columbia River's Carson Hatchery for the Comparative Survival Study.**

**1998 PIT Tag Releases**

<b>Tagging Site (code)</b>	<b>Tagging Dates</b>	<b>Coord ID</b>	<b>Release Site (code)</b>	<b>Release Dates</b>	<b>Release Number</b>
Carson NFH (CARS)	1/6-1/8/98 and 3/6/98	LRB	Carson H, Wind R (CARS)	4/20/98	7,491
Dworshak NFH (DWOR)	2/9-3/9/98	HLB	NF Clearwater R (CLWRNF)	3/25 and 3/26/98	47,704
McCall SFH (MCCA)	2/17-2/19/98	LRB	SF Salmon R (Knox Br) (KNOXB)	3/30/98	47,340
Rapid River SFH (RAPH)	2/9-2/11/98		Rapid River Hatchery (RAPH)	Volitional release median 4/13/98	48,339
Lookingglass SFH (LOOH)	2/17-2/23/98	PMS	Imnaha R Weir (IMNAHW)	4/6/98	19,827
	2/23-3/6/98		Lookingglass Hatchery (LOOH)	4/6/98	44,234

Release date for Rapid River Hatchery for 1998 is estimated median date of 1-month volitional release.

**Table A-4. Number of hatchery chinook smolts from the 1999 migration year PIT tagged and released from Snake River Basin hatcheries and lower Columbia River's Carson Hatchery for the Comparative Survival Study.**

**1999 PIT Tag Releases**

<b>Tagging Site (code)</b>	<b>Tagging Dates</b>	<b>Coord ID</b>	<b>Release Site (code)</b>	<b>Release Dates</b>	<b>Release Number</b>
Carson NFH (CARS)	4/9/99	LRB	Carson H, Wind R (CARS)	4/20/99	12,977
Dworshak NFH (DWOR)	2/10-3/8/99	HLB	NF Clearwater R (CLWRNF)	4/7-4/8/99	47,845
McCall SFH (MCCA)	2/16-2/18/99	LRB	SF Salmon R (Knox Br) (KNOXB)	4/6/99	47,985
Rapid River SFH (RAPH)	2/9-2/11/99		Rapid River Hatchery (RAPH)	Volitional release median 4/2/99	47,813
Lookingglass SFH (LOOH)	11/9/98; 2/1-2/3/99	PMS	Imnaha R Weir (IMNAHW)	Volitional release start 3/16/99	19,939
	11/2-11/3/98; 2/4-2/10/99		Lookingglass Hatchery (LOOH)	Volitional release start 3/15/99	44,554

Release date for Rapid River Hatchery for 1999 is estimated median date of 1-month volitional release.

Release date for Imnaha R acclimation pond and Lookingglass Hatchery for 1999 is start of 1-month volitional release.

**Table A-5. Number of hatchery chinook smolts from the 2000 migration year PIT tagged and released from Snake River Basin hatcheries and lower Columbia River's Carson Hatchery for the Comparative Survival Study.**

**2000 PIT Tag Releases**

<b>Tagging Site (code)</b>	<b>Tagging Dates</b>	<b>Coord ID</b>	<b>Release Site (code)</b>	<b>Release Dates</b>	<b>Release Number</b>
Carson NFH (CARS)	1/3-1/7/00; 3/29-3/30/00	LRB	Carson H, Wind R (CARS)	4/20/00	14,992
Dworshak NFH (DWOR)	2/16-3/15/00	HLB	NF Clearwater R (CLWRNF)	3/23/00; 4/5-4/6/00	47,745
McCall SFH (MCCA)	2/14-2/16/00; 3/9/00	LRB	SF Salmon R (Knox Br) (KNOXB)	4/5/00	47,709
Rapid River SFH (RAPH)	2/7-2/10/00		Rapid River Hatchery (RAPH)	Volitional release start 3/17/00	47,748
Lookingglass SFH (LOOH)	10/18- 10/22/99	PMS	Imnaha R Weir (IMNAHW)	Volitional release start 3/22/00	20,819

Release date for Rapid River Hatchery and Imnaha River acclimation pond for 2000 is start of 1-month volitional release.

**Table A-6. Brief description of hatcheries providing PIT tagged chinook for the CSS.**

<p><b>Rapid River Hatchery</b> is located about 3 miles upstream from the confluence of Rapid River with the Little Salmon River, and approximately 7 miles from the nearest town of Riggins, Idaho. Idaho Power Company funds Idaho Department of Fish and Game to operate and rear yearling spring chinook salmon to mitigate for the Idaho Power Hydroelectric Dams, Brownlee, Oxbow, and Hells Canyon. The hatchery uses water from Rapid River as its source of water to incubate and raise spring chinook salmon from eggs to yearling sized smolts in approximately 1.5 years. In a normal year, approximately 3.0 million yearling chinook salmon are released from this facility, and this total comprises about one-third of the yearling chinook salmon released in the state of Idaho. Rapid River Hatchery was selected because of its importance as a mitigation hatchery.</p>
<p><b>McCall Hatchery</b> is located in McCall, Idaho and operated by IDFG with funding from the US Army Corps of Engineers as part of the Lower Snake Compensation Program for mitigation for construction of the four lower Snake River Dams. The hatchery's water source is the Payette Lake. Annually, hatchery personnel capture adult fish at the South Fork Salmon River, spawn them at that site, and then transport the green eggs to the hatchery. The resulting fish are reared for about 1.5 years at the hatchery and trucked back to the South Fork of the Salmon River for release near Knox Bridge. The capacity of the two holding ponds is about 1,000,000 yearling summer chinook salmon. McCall Hatchery was selected because of the importance of these fish to the total summer chinook production in the Salmon River basin.</p>
<p><b>Pahsimeroi Hatchery</b> is located about one mile upstream from the confluence of the Pahsimeroi River with the main Salmon River and near Ellis, Idaho. The Idaho Department of Fish and Game operates the hatchery with funding from Idaho Power Company. IDFG PIT tagged summer chinook salmon at Sawtooth Hatchery in fall 1996 for eventual release from Pahsimeroi Hatchery in spring of 1997. Pahsimeroi Hatchery summer chinook were used for the CSS only in 1997. This stock was not chosen for the longer term study because its track record of releases and subsequent adult returns would be hit and miss. Because hatchery numbers elsewhere were so reduced in 1997, Pahsimeroi Hatchery fish were needed to help achieve the CSS goal of 200,000 chinook to be PIT tagged for the Snake River Basin in 1997.</p>
<p><b>Lookingglass Hatchery</b> is located in Northeastern Oregon, about 1.5 miles upstream from the confluence of Lookingglass Creek with the Grande Ronde River. The hatchery is operated by ODFW with hatchery funding provided by the US Army Corps of Engineers as part of the Lower Snake Compensation Program for mitigation of fish losses due to construction of the four lower Snake River dams. Approximately 500,000 yearling spring chinook are slated for release from this hatchery on an annual basis. In addition to the on-site releases, the hatchery rears fish that are released from the <b>Imnaha Acclimation Pond</b>, as well as some captive brood programs initiated due to listing of some chinook stocks under the Endangered Species Act. Lookingglass Hatchery was chosen to represent spring chinook from the Grande Ronde River. However, the Lookingglass Hatchery stock was a derivative of the Rapid River stock, and ODFW discontinued production of this stock after migration year 1999. Starting 2000, Lookingglass Hatchery is rearing only stocks indigenous to the Grande Ronde River basin for release at acclimation ponds on the Lostine River, Catherine Creek, and upper Grande Ronde River.</p>
<p><b>Imnaha Acclimation Pond</b> is located about 34 miles upstream from the mouth of the Imnaha River with the Snake River. All returning adult salmon are captured at the Imnaha River weir when it operates and designated adult fish hauled by truck to Lookingglass Hatchery for spawning. The rearing portion of the fish's life cycle occurs at Lookingglass Hatchery. The</p>

yearling chinook are trucked back to the Imnaha facility in February and acclimated for approximately one month before release. Most adult salmon returning to the Imnaha weir pass Lower Granite Dam at a time when they would be counted as summer chinook stocks. This facility is operated by ODFW to mitigate for construction of the Lower Snake River dams, using funds from Lower Snake River Compensation Plan. Since the Imnaha River historically was a very productive stream with thousands of salmon returning to spawn, its was selected for inclusion in the CSS.

**Dworshak National Fish Hatchery** is located within the small town of Ahsahka, Idaho, about 32 river miles upstream of the confluence of the Clearwater River with the Snake River. Dworshak NFH is operated by the USFWS, and annually produces juvenile spring chinook and summer steelhead salmon for release into the Clearwater River basin. Up to 1 million yearling spring chinook are released from the hatchery to compensate for operation of the lower Snake River dams. Dworshak NFH was selected because of the importance of these fish to the total spring chinook production in the Clearwater River basin.

**Kooskia National Fish Hatchery** is located 1 km up Clear Creek, which joins the South Fork of the Clearwater River near the town of Kooskia, Idaho. The facility is operated by the USFWS, and produces about 500,000 yearling chinook for release from the hatchery on an annual basis. Kooskia NFH is part of the Dworshak NFH complex. After migration year 1997, the CSS discontinued using Kooskia NFH fish and concentrated all tagging at Dworshak NFH.

**Carson National Fish Hatchery** is located about 28 Km up from the mouth of the Wind River, near Carson, WA. The hatchery raises spring chinook salmon to yearling age that are released directly into the Wind River and adult fish return to a small fish ladder that leads into the hatchery. The normal production released from the hatchery is about 1.4 million yearling chinook, with additional fish reared for off-site releases. The USFWS operates Carson NFH with funding provided by the NMFS through Mitchell Act appropriations. Carson Hatchery fish have only to traverse the Wind River and a small section of Bonneville pool before being in the free flowing Columbia River below Bonneville Dam. This stock of fish was added to the downstream portion of the CSS because of its large production and more similar genetic background to the upriver stocks used in the CSS.

## **Appendix B**

**Estimated number of hatchery chinook smolts in key categories,  
SARs, and ratios of SARs, with 95% confidence intervals.**

**Table B-1. Estimated number of smolts per category (actual number in Category T<sub>igr</sub>) with associated 95% confidence intervals for migration year 1997.**

Hatchery	Statistic	T <sub>igr</sub>	T <sub>0</sub>	C <sub>1</sub>	C <sub>0</sub>
Rapid River H	Lower limit		4315	6585	3465
	Point estimate	4138	4324	6863	4176
	Upper limit		4334	7173	4859
	CI width(%)		0.22%	4.28%	16.69%
McCall H	Lower limit		6006	8928	5868
	Point estimate	5863	6013	9288	6761
	Upper limit		6020	9665	7651
	CI width(%)		0.12%	3.97%	13.19%
Dworshak— Kooskia H Complex	Lower limit		2324	4267	2386
	Point estimate	2236	2330	4523	3046
	Upper limit		2337	4841	3640
	CI width(%)		0.28%	6.35%	20.58%
Imnaha AP	Lower limit		2143	3597	1662
	Point estimate	2086	2147	3792	2219
	Upper limit		2152	4051	2704
	CI width(%)		0.21%	5.99%	23.48%
Lookingglass H	Lower limit		6203	10795	5513
	Point estimate	6029	6210	11141	6349
	Upper limit		6217	11533	7215
	CI width(%)		0.11%	3.31%	13.40%
Pahsimeroi H	Lower limit		5028	6528	3547
	Point estimate	4864	5036	6774	4196
	Upper limit		5045	7060	4812
	CI width(%)		0.17%	3.93%	15.07%

**Table B-2. Estimated number of smolts per category (actual number in Category T<sub>igr</sub>) with associated 95% confidence intervals for migration year 1998.**

Hatchery	Statistic	T <sub>igr</sub>	T <sub>0</sub>	C <sub>1</sub>	C <sub>0</sub>
Rapid River H	Lower limit		12835	13448	3605
	Point estimate	11290	12884	13700	4323
	Upper limit		12935	13974	5034
	CI width(%)		0.39%	1.92%	16.53%
McCall H	Lower limit		10121	12706	3412
	Point estimate	9045	10144	12885	3853
	Upper limit		10169	13071	4264
	CI width(%)		0.24%	1.42%	11.06%
Dworshak H	Lower limit		14598	12894	7553
	Point estimate	11113	14965	13558	10505
	Upper limit		15455	14452	13074
	CI width(%)		2.86%	5.75%	26.28%
Imnaha AP	Lower limit		4750	5901	1562
	Point estimate	4061	4774	6032	1916
	Upper limit		4798	6165	2281
	CI width(%)		0.50%	2.19%	18.76%
Lookingglass H	Lower limit		12719	11722	3891
	Point estimate	10841	12827	12118	5088
	Upper limit		12964	12584	6297
	CI width(%)		0.96%	3.56%	23.64%

**Table B-3. Estimated number of smolts per category (actual number in Category T<sub>igr</sub>) with associated 95% confidence intervals for migration year 1999.**

Hatchery	Statistic	T <sub>igr</sub>	T <sub>0</sub>	C <sub>1</sub>	C <sub>0</sub>
Rapid River H	Lower limit		12625	14022	5356
	Point estimate	7405	12895	14523	7156
	Upper limit		13207	15107	8915
	CI width(%)		2.26%	3.74%	24.87%
McCall H	Lower limit		10101	10786	5691
	Point estimate	4760	10567	11465	8327
	Upper limit		11137	12225	10945
	CI width(%)		4.90%	6.28%	31.55%
Dworshak H	Lower limit		9400	17813	5655
	Point estimate	4934	9848	19227	10465
	Upper limit		10481	21160	14809
	CI width(%)		5.49%	8.70%	43.74%
Imnaha AP	Lower limit		4738	4961	2264
	Point estimate	2181	4856	5114	2877
	Upper limit		4983	5289	3455
	CI width(%)		2.52%	3.21%	20.70%
Lookingglass H	Lower limit		5939	17235	3560
	Point estimate	5168	5966	17812	4775
	Upper limit		5995	18437	6086
	CI width(%)		0.47%	3.37%	26.45%

**Table B-4. Estimated number of smolts per category (actual number in Category T<sub>lgr</sub>) with associated 95% confidence intervals for migration year 2000.**

Hatchery	Statistic	Category T <sub>lgr</sub>	Category T <sub>0</sub>	Category C <sub>1</sub>	Category C <sub>0</sub>
Rapid River H	Lower limit		15769	5195	10750
	Point estimate	10258	16107	5265	12096
	Upper limit		16572	5350	13317
	CI width(%)		2.49%	1.47%	10.61%
McCall H	Lower limit		12467	4537	11768
	Point estimate	8451	12839	4644	13285
	Upper limit		13225	4761	14769
	CI width(%)		2.95%	2.41%	11.29%
Dworshak H	Lower limit		17748	5398	11974
	Point estimate	9699	18231	5531	13806
	Upper limit		18829	5673	15393
	CI width(%)		2.96%	2.49%	12.38%
Imnaha AP	Lower limit		6565	2243	3899
	Point estimate	3880	6749	2290	4552
	Upper limit		6982	2344	5151
	CI width(%)		3.09%	2.21%	13.75%

**Table B-5. Estimated smolt-to-adult survival rates (SAR's) per category with associated 95% confidence intervals for migration year 1997. Adults excluding jacks.**

Hatchery	Statistic	T <sub>lgr</sub>	T <sub>0</sub> '	C <sub>1</sub>	C <sub>0</sub>
Rapid River H	Lower limit	0.0053	0.0053	0.0035	0.0025
	Median	0.0080	0.0079	0.0052	0.0045
	Upper limit	0.0106	0.0104	0.0070	0.0069
	CI width(%)	33.13%	32.28%	33.65%	48.89%
McCall H	Lower limit	0.0119	0.0121	0.0087	0.0082
	Median	0.0148	0.0150	0.0109	0.0109
	Upper limit	0.0181	0.0183	0.0133	0.0139
	CI width(%)	20.95%	20.67%	21.10%	26.15%
Dworshak— Kooskia H Complex	Lower limit	0.0049	0.0043	0.0014	0.0020
	Median	0.0085	0.0081	0.0031	0.0043
	Upper limit	0.0125	0.0120	0.0048	0.0070
	CI width(%)	44.71%	47.53%	54.84%	58.14%
Imnaha AP	Lower limit	0.0072	0.0070	0.0043	0.0048
	Median	0.0120	0.0116	0.0069	0.0086
	Upper limit	0.0168	0.0158	0.0094	0.0140
	CI width(%)	40.00%	37.93%	36.96%	53.49%
Lookingglass H	Lower limit	0.0022	0.0023	0.0024	0.0039
	Median	0.0036	0.0037	0.0035	0.0059
	Upper limit	0.0053	0.0052	0.0045	0.0080
	CI width(%)	43.06%	39.19%	30.00%	34.75%
Pahsimeroi H	Lower limit	0.0023	0.0022	0.0003	0.0009
	Median	0.0039	0.0038	0.0012	0.0022
	Upper limit	0.0058	0.0056	0.0020	0.0037
	CI width(%)	44.87%	44.74%	70.83%	63.64%

**Table B-6. Estimated smolt-to-adult survival rates (SAR's) per category with associated 95% confidence intervals for migration year 1998. Adults excluding jacks.**

Hatchery	Statistic	T <sub>igr</sub>	T <sub>0'</sub>	C <sub>1</sub>	C <sub>0</sub>
Rapid River H	Lower limit	0.0183	0.0175	0.0053	0.0086
	Median	0.0212	0.0199	0.0066	0.0123
	Upper limit	0.0240	0.0223	0.0080	0.0165
	CI width(%)	13.44%	12.06%	20.45%	32.11%
McCall H	Lower limit	0.0255	0.0239	0.0059	0.0097
	Median	0.0290	0.0268	0.0073	0.0137
	Upper limit	0.0322	0.0301	0.0088	0.0180
	CI width(%)	11.55%	11.57%	19.86%	30.29%
Dworshak H	Lower limit	0.0081	0.0072	0.0071	0.0102
	Median	0.0099	0.0088	0.0087	0.0133
	Upper limit	0.0117	0.0104	0.0103	0.0184
	CI width(%)	18.18%	18.18%	18.39%	30.83%
Imnaha AP	Lower limit	0.0062	0.0059	0.0018	0.0024
	Median	0.0091	0.0086	0.0031	0.0058
	Upper limit	0.0118	0.0113	0.0046	0.0095
	CI width(%)	30.77%	31.40%	45.16%	61.21%
Lookingglass H	Lower limit	0.0032	0.0031	0.0008	0.0004
	Median	0.0045	0.0043	0.0015	0.0014
	Upper limit	0.0057	0.0055	0.0021	0.0026
	CI width(%)	27.78%	27.91%	43.33%	78.57%

**Table B-7. Estimated smolt-to-adult survival rates (SAR's) per category with associated 95% confidence intervals for migration year 1999. Adults excluding jacks.**

Hatchery	Statistic	T <sub>igr</sub>	T <sub>0'</sub>	C <sub>1</sub>	C <sub>0</sub>
Rapid River H	Lower limit	0.0271	0.0264	0.0135	0.0164
	Median	0.0312	0.0293	0.0156	0.0217
	Upper limit	0.0347	0.0323	0.0179	0.0298
	CI width(%)	12.18%	10.07%	14.10%	30.88%
McCall H	Lower limit	0.0330	0.0273	0.0145	0.0144
	Median	0.0382	0.0307	0.0171	0.0200
	Upper limit	0.0433	0.0343	0.0197	0.0299
	CI width(%)	13.48%	11.40%	15.20%	38.75%
Dworshak H	Lower limit	0.0083	0.0087	0.0070	0.0068
	Median	0.0116	0.0108	0.0084	0.0104
	Upper limit	0.0146	0.0129	0.0099	0.0194
	CI width(%)	27.16%	19.44%	17.26%	60.58%
Imnaha AP	Lower limit	0.0225	0.0199	0.0084	0.0083
	Median	0.0298	0.0242	0.0114	0.0132
	Upper limit	0.0371	0.0285	0.0142	0.0188
	CI width(%)	24.50%	17.77%	25.44%	39.77%
Lookingglass H	Lower limit	0.0054	0.0053	0.0043	0.0036
	Median	0.0077	0.0075	0.0054	0.0059
	Upper limit	0.0103	0.0097	0.0064	0.0091
	CI width(%)	31.82%	29.33%	19.44%	46.61%

**Table B-8. Estimated smolt-to-adult, including jacks, survival rates (SAR's) per category with associated 95% confidence intervals at hatcheries where total return is composed of more than 10% jacks.**

<b>Migration year/ Hatchery</b>	<b>Statistic</b>	<b>T<sub>lgr</sub></b>	<b>T<sub>0</sub>'</b>	<b>C<sub>1</sub></b>	<b>C<sub>0</sub></b>
1997 Imnaha H	Lower limit	0.0120	0.0117	0.0060	0.0058
	Median	0.0177	0.0172	0.0090	0.0100
	Upper limit	0.0235	0.0224	0.0119	0.0158
	CI width(%)	32.49%	31.10%	32.78%	50.00%
1998 Dworshak H	Lower limit	0.0094	0.0083	0.0077	0.0118
	Median	0.0113	0.0101	0.0094	0.0154
	Upper limit	0.0132	0.0117	0.0111	0.0214
	CI width(%)	16.81%	16.83%	18.09%	31.17%
1998 Imnaha H	Lower limit	0.0128	0.0120	0.0032	0.0054
	Median	0.0167	0.0157	0.0050	0.0099
	Upper limit	0.0204	0.0194	0.0068	0.0150
	CI width(%)	22.75%	23.57%	36.00%	48.48%
1998 McCall H	Lower limit	0.0312	0.0294	0.0078	0.0138
	Median	0.0349	0.0327	0.0094	0.0187
	Upper limit	0.0385	0.0362	0.0111	0.0238
	CI width(%)	10.46%	10.40%	17.55%	26.74%
1999 Imnaha H	Lower limit	0.0303	0.0282	0.0122	0.0116
	Median	0.0385	0.0332	0.0158	0.0173
	Upper limit	0.0468	0.0383	0.0190	0.0239
	CI width(%)	21.43%	15.21%	21.52%	35.55%
1999 McCall H	Lower limit	0.0382	0.0319	0.0169	0.0179
	Median	0.0439	0.0356	0.0197	0.0243
	Upper limit	0.0492	0.0395	0.0224	0.0359
	CI width(%)	12.53%	10.67%	13.96%	37.04%

**Table B-9. Ratios of selected SAR's with associated 95% confidence intervals for migration year 1997. Adults excluding jacks.**

Hatchery	Statistic	$SAR_{Tigr}/SAR_{C0}$	$SAR_{T0}/SAR_{C0}$	$SAR_{C1}/SAR_{C0}$
Rapid River H	Lower limit	1.003	0.957	0.627
	Median	1.755	1.713	1.152
	Upper limit	3.345	3.479	2.223
	CI width(%)	66.72%	73.61%	69.30%
McCall H	Lower limit	0.977	0.989	0.721
	Median	1.357	1.378	1.000
	Upper limit	1.901	1.910	1.364
	CI width(%)	34.08%	33.42%	32.16%
Dworshak— Kooskia H Complex	Lower limit	0.960	0.915	0.281
	Median	1.971	1.867	0.717
	Upper limit	4.729	4.654	1.823
	CI width(%)	95.61%	100.14%	107.60%
Imnaha AP	Lower limit	0.742	0.696	0.396
	Median	1.374	1.313	0.802
	Upper limit	2.745	2.666	1.575
	CI width(%)	72.91%	75.03%	73.49%
Lookingglass H	Lower limit	0.340	0.332	0.363
	Median	0.625	0.631	0.600
	Upper limit	1.080	1.104	0.996
	CI width(%)	59.19%	61.15%	52.72%
Pahsimeroi H	Lower limit	0.869	0.807	0.169
	Median	1.772	1.729	0.537
	Upper limit	4.885	4.424	1.482
	CI width(%)	113.28%	104.62%	122.30%

**Table B-10. Ratios of selected SAR's with associated 95% confidence intervals for migration year 1998. Adults excluding jacks.**

Hatchery	Statistic	SAR <sub>Tigr</sub> /SAR <sub>C0</sub>	SAR <sub>T0</sub> /SAR <sub>C0</sub>	SAR <sub>C1</sub> /SAR <sub>C0</sub>
Rapid River H	Lower limit	1.236	1.156	0.363
	Median	1.721	1.609	0.538
	Upper limit	2.545	2.446	0.828
	CI width(%)	38.02%	40.09%	43.24%
McCall H	Lower limit	1.592	1.446	0.378
	Median	2.103	1.959	0.531
	Upper limit	2.985	2.775	0.780
	CI width(%)	33.12%	33.95%	37.90%
Dworshak H	Lower limit	0.510	0.443	0.427
	Median	0.744	0.665	0.656
	Upper limit	1.033	0.921	0.916
	CI width(%)	35.17%	35.92%	37.30%
Imnaha AP	Lower limit	0.827	0.794	0.264
	Median	1.596	1.506	0.543
	Upper limit	3.867	3.841	1.448
	CI width(%)	95.22%	101.13%	109.01%
Lookingglass H	Lower limit	1.594	1.554	0.430
	Median	3.226	3.171	1.086
	Upper limit	12.109	11.341	3.666
	CI width(%)	160.96%	154.32%	148.97%

**Table B-11. Ratios of selected SAR's with associated 95% confidence intervals for migration year 1999. Adults excluding jacks.**

Hatchery	Statistic	SAR <sub>Tigr</sub> /SAR <sub>C0</sub>	SAR <sub>T0</sub> /SAR <sub>C0</sub>	SAR <sub>C1</sub> /SAR <sub>C0</sub>
Rapid River H	Lower limit	1.018	0.959	0.500
	Median	1.435	1.351	0.724
	Upper limit	1.950	1.841	0.987
	CI width(%)	32.48%	32.66%	33.69%
McCall H	Lower limit	1.278	1.015	0.558
	Median	1.904	1.537	0.852
	Upper limit	2.637	2.140	1.220
	CI width(%)	35.68%	36.60%	38.87%
Dworshak H	Lower limit	0.563	0.532	0.405
	Median	1.104	1.037	0.810
	Upper limit	1.754	1.699	1.302
	CI width(%)	53.97%	56.27%	55.35%
Imnaha AP	Lower limit	1.471	1.211	0.545
	Median	2.267	1.820	0.863
	Upper limit	3.821	2.964	1.420
	CI width(%)	51.84%	48.16%	50.68%
Lookingglass H	Lower limit	0.743	0.723	0.546
	Median	1.322	1.284	0.908
	Upper limit	2.324	2.231	1.534
	CI width(%)	59.80%	58.72%	54.45%

## **Appendix C**

### **In-river survival data for Snake River spring/summer hatchery chinook**

Hatchery	<b>Rapid River</b>		enter data in golden cells from survival output
Mig_year	<b>1997</b>		computed values in green cells
From Program Release Output		Test chi_sq	df
		13.446	15
		1.00	<==c-hat
			note: c-hat<1 set c-hat=1
	se	Estimate	c-hat adj se
S <sub>1</sub>	0.007639	0.389312	0.007639
S <sub>2</sub>	0.029726	0.963830	0.029726
S <sub>3</sub>	0.029726	0.803378	0.029726
S <sub>2</sub> *S <sub>3</sub>		0.77432	0.032552
			corr(S <sub>2</sub> ,S <sub>3</sub> )
			-0.242273
			R <sub>1</sub>
			40495
			m <sub>12</sub>
			5449
			m <sub>13</sub>
			3626
			m <sub>14</sub>
			1840
			<=used variance of dependent random variables

Hatchery	<b>McCall</b>		enter data in golden cells from survival output
Mig_year	<b>1997</b>		computed values in green cells
From Program Release Output		Test chi_sq	df
		8.0711	16
		1.00	<==c-hat
			note: c-hat<1 set c-hat=1
	se	Estimate	c-hat adj se
S <sub>1</sub>	0.007618	0.425066	0.007618
S <sub>2</sub>	0.026473	0.935496	0.026473
S <sub>3</sub>	0.034356	0.882177	0.034356
S <sub>2</sub> *S <sub>3</sub>		0.825273	0.035436
			corr(S <sub>2</sub> ,S <sub>3</sub> )
			-0.214963
			R <sub>1</sub>
			52653
			m <sub>12</sub>
			7544
			m <sub>13</sub>
			5022
			m <sub>14</sub>
			2235
			<=used variance of dependent random variables

Hatchery	<b>Dworshak-- Kooskia</b>		enter data in golden cells from survival output
Mig_year	<b>1997</b>		computed values in green cells
From Program Release Output		Test chi_sq	df
		14.4065	13
		1.11	<==c-hat
			note: c-hat<1 set c-hat=1
	se	Estimate	c-hat adj se
S <sub>1</sub>	0.015108	0.552397	0.015904
S <sub>2</sub>	0.043419	1.000000	0.045707
S <sub>3</sub>	0.040321	0.807355	0.042446
S <sub>2</sub> *S <sub>3</sub>		0.807355	0.049152
			corr(S <sub>2</sub> ,S <sub>3</sub> )
			-0.238628
			R <sub>1</sub>
			18155
			m <sub>12</sub>
			2890
			m <sub>13</sub>
			2583
			m <sub>14</sub>
			1217
			<=used variance of dependent random variables

Hatchery	<b>Imnaha</b>		enter data in golden cells from survival output
Mig_year	<b>1997</b>		computed values in green cells
From Program Release Output		Test chi_sq	df
		6.5376	13
		1.00	<==c-hat
			note: c-hat<1 set c-hat=1
	se	Estimate	c-hat adj se
S <sub>1</sub>	0.016918	0.616960	0.016918
S <sub>2</sub>	0.042162	0.994199	0.042162
S <sub>3</sub>	0.041189	0.768430	0.041189
S <sub>2</sub> *S <sub>3</sub>		0.763972	0.045648
			corr(S <sub>2</sub> ,S <sub>3</sub> )
			-0.242273
			R <sub>1</sub>
			13378
			m <sub>12</sub>
			2644
			m <sub>13</sub>
			2139
			m <sub>14</sub>
			945
			<=used variance of dependent random variables

Hatchery	Lookingglass	enter data in golden cells from survival output				
Mig_year	1997	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		16.3663	16			
		1.02	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub> 40027	
S <sub>1</sub>	0.009490	0.599326	0.009598		m <sub>12</sub> 7716	
S <sub>2</sub>	0.022959	0.950557	0.023220		m <sub>13</sub> 5707	
S <sub>3</sub>	0.020957	0.803740	0.021196	-0.24525	m <sub>14</sub> 2995	
S2*S3		0.764001	0.023870	<=used variance of dependent random variables		

Hatchery	Pahsimeroi	enter data in golden cells from survival output				
Mig_year	1997	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		8.0545	16	note: c-hat<1		
		1.00	<==c-hat set c-hat=1			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub> 33432	
S <sub>1</sub>	0.008166	0.490877	0.008166		m <sub>12</sub> 6374	
S <sub>2</sub>	0.027103	0.967121	0.027103		m <sub>13</sub> 3744	
S <sub>3</sub>	0.032241	0.854477	0.032241	-0.244507	m <sub>14</sub> 1626	
S2*S3		0.826383	0.033992	<=used variance of dependent random variables		

Hatchery	Rapid River	enter data in golden cells from survival output				
Mig_year	1998	computed values in green cells				
From Program Release Output		Test chi_sq	df			
S <sub>2</sub> = 1.005563 set to 1.0		63.2006	17			
S <sub>3</sub> set to original S <sub>2</sub> *S <sub>3</sub>		3.72	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub> 48339	
S <sub>1</sub>	0.003530	0.664441	0.006806		m <sub>12</sub> 16409	
S <sub>2</sub>	0.009320	1.000000	0.017970		m <sub>13</sub> 7678	
S <sub>3</sub>	0.011203	0.849276	0.021601	-0.381559	m <sub>14</sub> 3134	
S2*S3		0.849276	0.021165	<=used variance of dependent random variables		

Hatchery	McCall	enter data in golden cells from survival output				
Mig_year	1998	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		23.0467	17			
		1.36	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub> 47340	
S <sub>1</sub>	0.003830	0.587986	0.004459		m <sub>12</sub> 13083	
S <sub>2</sub>	0.010349	0.989522	0.012050		m <sub>13</sub> 7062	
S <sub>3</sub>	0.011483	0.842682	0.013370	-0.346529	m <sub>14</sub> 3106	
S2*S3		0.833852	0.013603	<=used variance of dependent random variables		

Hatchery	<b>Dworshak</b>	enter data in golden cells from survival output			
Mig_year	<b>1998</b>	computed values in green cells			
From Program Release Output		Test chi_sq	df		
$S_2 = 1.068450$ set to 1.0		277.4135	17		
$S_3$ set to original $S_2 * S_3$		16.32	<==c-hat		
	se	Estimate	c-hat adj se	corr( $S_2, S_3$ )	$R_1$ 47704
$S_1$	0.006007	0.842822	0.024266		$m_{12}$ 15418
$S_2$	0.014397	1.000000	0.058158		$m_{13}$ 9449
$S_3$	0.012834	0.817793	0.051844	-0.471394	$m_{14}$ 3929
$S_2 * S_3$		0.817793	0.051237	<=used variance of dependent random variables	

Hatchery	<b>Imnaha</b>	enter data in golden cells from survival output			
Mig_year	<b>1998</b>	computed values in green cells			
From Program Release Output		Test chi_sq	df		
		28.8552	17		
		1.70	<==c-hat		
	se	Estimate	c-hat adj se	corr( $S_2, S_3$ )	$R_1$ 19827
$S_1$	0.006188	0.661109	0.008062		$m_{12}$ 5848
$S_2$	0.014442	0.979615	0.018815		$m_{13}$ 3667
$S_3$	0.015726	0.838543	0.020488	-0.326406	$m_{14}$ 1315
$S_2 * S_3$		0.821449	0.021096	<=used variance of dependent random variables	

Hatchery	<b>Lookingglass</b>	enter data in golden cells from survival output			
Mig_year	<b>1998</b>	computed values in green cells			
From Program Release Output		Test chi_sq	df		
		137.0181	17		
		8.06	<==c-hat		
	se	Estimate	c-hat adj se	corr( $S_2, S_3$ )	$R_1$ 44234
$S_1$	0.004456		0.012651		$m_{12}$ 15153
$S_2$	0.011656	0.979954	0.033091		$m_{13}$ 7243
$S_3$	0.013680	0.817002	0.038837		$m_{14}$ 2684
$S_2 * S_3$		0.800624	0.037620	<=used variance of dependent random variables	

Hatchery	<b>Rapid River</b>	enter data in golden cells from survival output			
Mig_year	<b>1999</b>	computed values in green cells			
From Program Release Output		Test chi_sq	df		
		105.6263	17		
		6.21	<==c-hat		
	se	Estimate	c-hat adj se	corr( $S_2, S_3$ )	$R_1$ 47813
$S_1$	0.006501	0.752909	0.016205		$m_{12}$ 10057
$S_2$	0.010672	0.922832	0.026602		$m_{13}$ 12907
$S_3$	0.010498		0.026168	-0.211956	$m_{14}$ 4197
$S_2 * S_3$		0.884357	0.031178	<=used variance of dependent random variables	

Hatchery	McCall	enter data in golden cells from survival output				
Mig_year	1999	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		151.1575	17			
		8.89	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub>	
S <sub>1</sub>	0.008264	0.657170	0.024642		m <sub>12</sub>	
S <sub>2</sub>	0.014491	0.905481	0.043210		m <sub>13</sub>	
S <sub>3</sub>	0.013650	0.937917	0.040703	-0.246964	m <sub>14</sub>	
S2*S3		0.849266	0.047572	<=used variance of dependent random variables		

Hatchery	Dworshak	enter data in golden cells from survival output				
Mig_year	1999	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		236.1427	17			
		13.89	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub>	
S <sub>1</sub>	0.011393	0.854806	0.042462		m <sub>12</sub>	
S <sub>2</sub>	0.013999	0.882628	0.052175		m <sub>13</sub>	
S <sub>3</sub>	0.008857	0.953803	0.033010	-0.149558	m <sub>14</sub>	
S2*S3		0.841853	0.053774	<=used variance of dependent random variables		

Hatchery	Imnaha	enter data in golden cells from survival output				
Mig_year	1999	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		26.5325	17			
		1.56	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub>	
S <sub>1</sub>	0.011193	0.664802	0.013983		m <sub>12</sub>	
S <sub>2</sub>	0.019293	0.919616	0.024103		m <sub>13</sub>	
S <sub>3</sub>	0.017853	0.955463	0.022304	-0.20100	m <sub>14</sub>	
S2*S3		0.878659	0.027589	<=used variance of dependent random variables		

Hatchery	Lookingglass	enter data in golden cells from survival output				
Mig_year	1999	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		62.6548	17			
		3.69	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub>	
S <sub>1</sub>	0.006428	0.658207	0.012340		m <sub>12</sub>	
S <sub>2</sub>	0.011100	0.932811	0.021310		m <sub>13</sub>	
S <sub>3</sub>	0.007676	0.952253	0.014736	-0.139809	m <sub>14</sub>	
S2*S3		0.888272	0.022863	<=used variance of dependent random variables		

Hatchery	<b>Rapid River</b>	enter data in golden cells from survival output				
Mig_year	<b>2000</b>	computed values in green cells				
From Program Release Output		Test chi_sq	df			
S <sub>3</sub> = 1.122033 set to 1.0		45.5509	17			
S <sub>2</sub> set to original S <sub>2</sub> *S <sub>3</sub>		2.68	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub>	
S <sub>1</sub>	0.007160	0.747552	0.011720		m <sub>12</sub>	
S <sub>2</sub>	0.017158	0.922699	0.028086			
S <sub>3</sub>	0.061711		0.101015	-0.296084	m <sub>14</sub>	
S <sub>2</sub> *S <sub>3</sub>		0.922699	0.089029	<=used variance of dependent random variables		

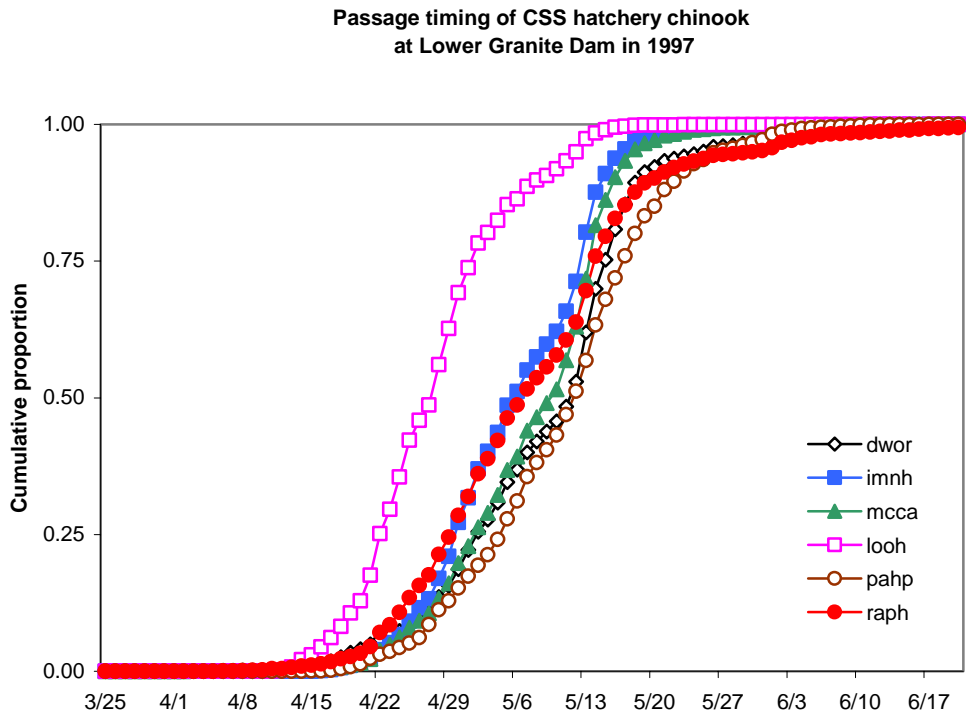
Hatchery	<b>McCall</b>	enter data in golden cells from survival output				
Mig_year	<b>2000</b>	computed values in green cells				
From Program Release Output		Test chi_sq	df			
		44.9954	17			
		2.65	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R	
S <sub>1</sub>	0.009068	0.676087	0.014753		m <sub>12</sub>	
S <sub>2</sub>	0.027258	0.842870	0.044346		m <sub>13</sub>	
S <sub>3</sub>	0.052768	0.905155	0.085848	-0.458426	m	
S <sub>2</sub> *S <sub>3</sub>		0.762928	0.064684	<=used variance of dependent random variables		

Hatchery	<b>Dworshak</b>	enter data in golden cells from survival output				
	<b>2000</b>	computed values in green cells				
		Test chi_sq	df			
S <sub>3</sub> = 1.038137 set to 1.0		52.4074	17			
S <sub>2</sub> set to original S <sub>2</sub> *S <sub>3</sub>		3.08	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub>	
S <sub>1</sub>	0.009139	0.841187	0.016046			
S	0.015666	0.813640	0.027506		m	
S	0.044502	1.000000	0.078136	-0.288961	m <sub>14</sub>	
S <sub>2</sub> *S <sub>3</sub>		0.81364	0.061544	<=used variance of dependent random variables		

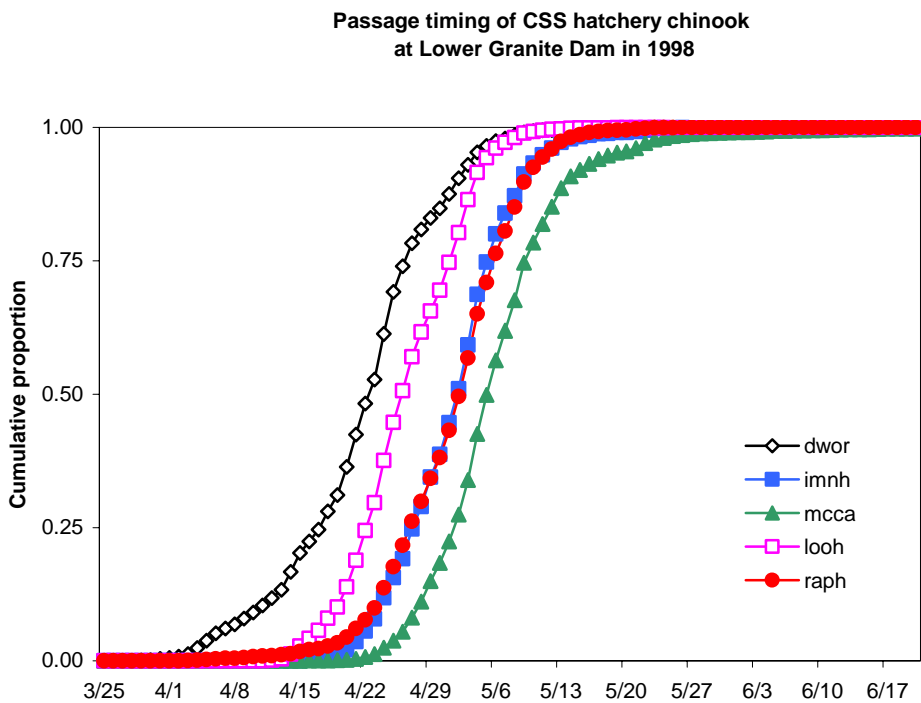
Hatchery	<b>Imnaha</b>	enter data in golden cells from survival output				
Mig_year	<b>2000</b>	computed values in green cells				
From Program Release Output		Test chi_sq	df			
S <sub>3</sub> = 1.025083 set to 1.0		26.3938	17			
S <sub>2</sub> set to original S <sub>2</sub> *S <sub>3</sub>		1.55	<==c-hat			
	se	Estimate	c-hat adj se	corr(S <sub>2</sub> ,S <sub>3</sub> )	R <sub>1</sub>	
S <sub>1</sub>	0.011141	0.692350	0.013882		m <sub>12</sub>	
S <sub>2</sub>	0.025939	0.825352	0.032321		m <sub>13</sub>	
S <sub>3</sub>	0.083362	1.000000	0.103871	-0.291588	m <sub>14</sub>	
S <sub>2</sub> *S <sub>3</sub>		0.825352	0.082331	<=used variance of dependent random variables		

## **Appendix D**

### **Migration timing plots at Lower Granite Dam for hatchery chinook**

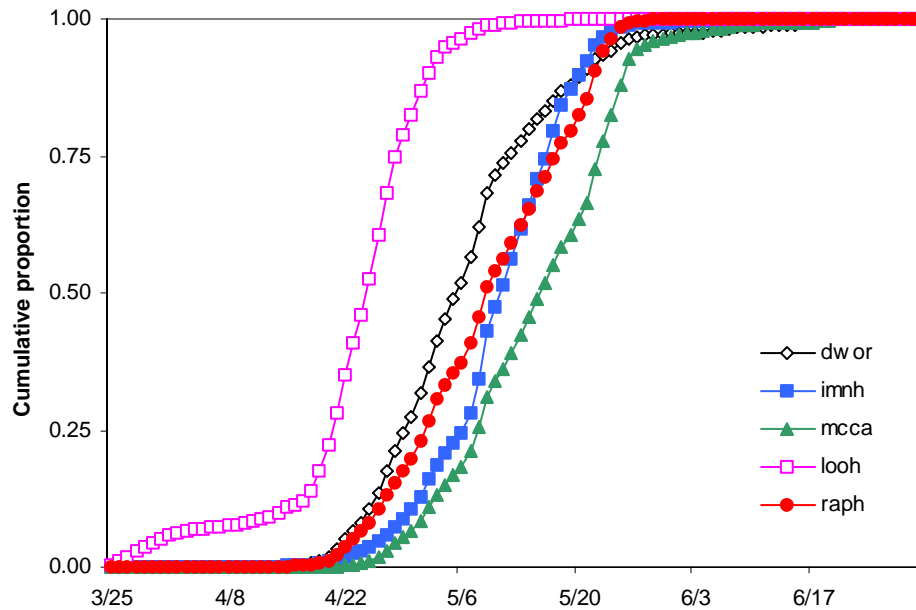


**Figure 1. Hatchery chinook migration timing at Lower Granite Dam in 1997.**  
 Legend: dwor=Dworshak/Kooskia H complex; imnh=Imnaha H; looh=Lookingglass H;  
 Mcca=McCall H; raph=Rapid River H; pahp=Pahsimeroi H.



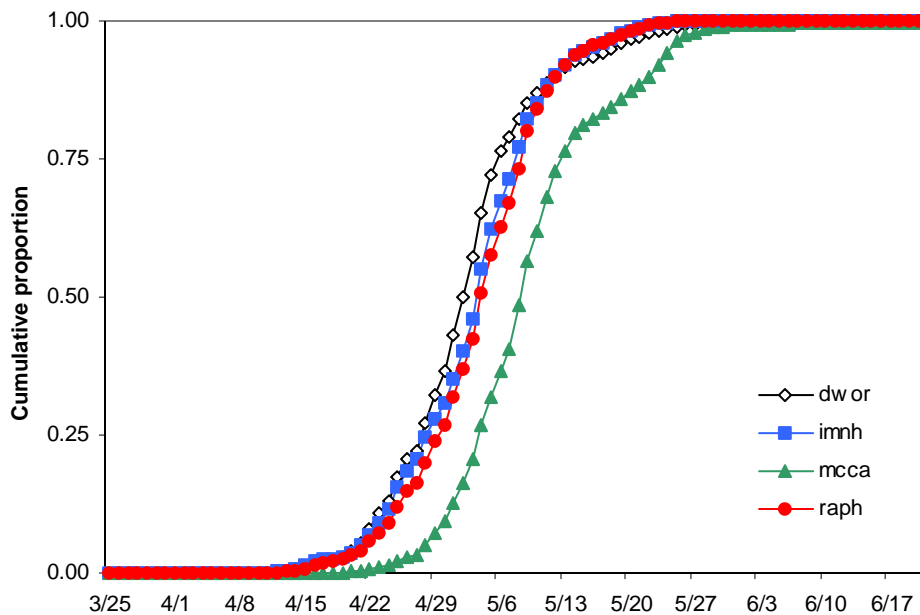
**Figure 2. Hatchery chinook migration timing at Lower Granite Dam in 1998.**  
 Legend: dwor=Dworshak/Kooskia H complex; imnh=Imnaha H; looh=Lookingglass H;  
 Mcca=McCall H; raph=Rapid River H.

Passage timing of CSS hatchery chinook  
at Lower Granite Dam in 1999



**Figure 3. Hatchery chinook migration timing at Lower Granite Dam in 1999.**  
Legend: dw or=Dworshak/Kooskia H complex; imnh=Imnaha H; looh=Lookingglass H;  
Mcca=McCall H; raph=Rapid River H.

Passage timing of CSS hatchery chinook  
at Lower Granite Dam in 2000



**Figure 4. Hatchery chinook migration timing at Lower Granite Dam in 2000.**  
Legend: dw or=Dworshak/Kooskia H complex; imnh=Imnaha H; Mcca=McCall H; raph=Rapid  
River H.

## **Appendix E**

### **Adult scale analysis**

## **Comparison of growth during residency in the estuary and ocean between transported and non-detected smolts and between upstream and downstream hatchery origin chinook**

Results of analyses evaluating the impacts of alternative management actions to recover endangered Snake River spring/summer chinook are highly dependent on the estuary and ocean survival of smolts that were transported around the Federal Columbia River Power System (referred to here after as the hydrosystem) relative to smolts that migrated through the hydrosystem (Marmorek and Peters 1998, Kariyeva et al. 2000). This relative survival has been referred to as 'D' and is the smolt-to-adult survival ratio (SAR-survival of smolts from Bonneville Dam, the lowest dam on the Columbia River, to adults back to Lower Granite Dam, the uppermost dam on the lower Snake River) of transported fish to fish that have migrated in-river. Estimates of 'D' are consistently less than 1 (see main section of this report), which equates to lower survival for transported fish than for fish that migrated in-river after they leave the hydrosystem.

Many mechanisms have been hypothesized for this difference in post-hydrosystem survival (see Budy et al. in press). However, very little information is available to determine which mechanisms are most likely. Recruitment success is thought to be determined during the early stages of a fishes' life history (Dragesund and Nakken 1973, Crecco et al. 1983), and increased growth rates in the early life stages has been suggested to be responsible for an increase in recruitment success (Rice et al. 1987, Miller et al. 1988, Luecke et al. 1990). Therefore, one possible mechanism that may explain this differential survival is that increased stress from transportation (crowding and premature saltwater entry) may result in decreased growth in the estuary and early ocean residence.

In addition to this comparison, analyses have also taken advantage of other stocks, that have to negotiate 1-3 rather than the 8 dams the Snake River stocks encounter, to discern more about factors affecting listed stocks (Deriso et al. 1996, Schaller et al. 1999, Budy et al. in press). This "upstream /downstream" (Snake River stocks/lower Columbia River stocks) comparison suggests that, in addition to the direct survival differences of migrating through more dams, upstream stocks also have reduced survival after the hydrosystem as a result of their experience in the hydrosystem relative to downstream stocks (Deriso et al. 1996). The mechanisms for this decreased post-hydrosystem survival is hypothesized to be similar to the mechanisms that result in differential survival between transported and in-river smolt.

Beginning in 1996 and expanding in 1997-2000, a given number of hatchery chinook have been marked with PIT tags from selected upriver and lower river hatcheries to measure survival from smolt to return as adult fish to Lower Granite Dam or to the hatchery of origin. PIT tags provide a history of a smolts' and adults' migration through the hydrosystem because the time and date of the unique tag number for each smolt is recorded when detected at dams fitted with PIT tag detectors. This marking of hatchery spring/summer chinook has been conducted under the Comparative Survival Study (CSS) in hopes of lending insight into the factors responsible for the decline of endangered wild stocks. The Fish Passage Center staff have been principal investigators for the CSS with oversight by a committee comprised of state, federal and tribal fishery agencies. One objective of the study was to analyze scale patterns from adult fish returning to Lower Granite Dam as well as at a selected hatchery in the lower Columbia River (Carson NFH). The purpose of evaluating scales from fish with known passage histories is to determine if different routes of passage through the hydrosystem (e.g. transported vs. in-river

migrants, upstream vs. downstream) results in differential growth rates throughout the rest of the salmon's life.

Marked CSS returning hatchery chinook have been captured at LGR or the hatcheries they originated from, and scales and other information were collected at capture. Scales provide a means to evaluate growth patterns of chinook with different hydrosystem experiences. We evaluated the growth patterns of smolts that were transported to growth patterns of smolts that migrated through the hydrosystem to test the hypothesis that increased stress due to transportation decreases growth rates. In addition, we tested whether downstream originating smolts grew faster after their migration through the hydrosystem than upstream originating smolts. If true, this evidence would provide a mechanism to explain the observed differential post-hydrosystem survival of transported fish to fish that migrated through the hydrosystem or between upstream and downstream stocks.

Personnel working at the Lower Granite adult trap have been collecting scales from PIT tagged chinook for the FPC. PIT tag and other information collected for each fish included: juvenile release length, adult length, sex, migration year, age, and passage history. Scales from the 1999 and 2000 adult chinook migrations were gathered, pressed and mounted by Oregon Department of Fish and Wildlife and Pacific States Marine Fisheries Commission personnel. Scales and information were also collected from adults returning to the Carson hatchery, representing hatcheries located downstream from Snake river hatcheries. For each fish, six scale impressions were made by pressing scales onto acetate cards.

Scales were measured from the center (focus) of the scale to: the outside edge (longest axis); the freshwater annulus (FA); ocean entry (OE); and ocean annulus (OA). In addition, the number of circuli between OE and OA and the edge were counted. Only the most readable scale from each fish was measured. All scales were read at least twice and averaged. When scales had large variation or were hard to read, they were read by a third reader (about 300 scales), and the final measurement was then determined by averaging the two closest readings. A total of 700 and 777 Snake River hatchery fish scales, for 1999 and 2000 return years, respectively, were readable. Scales from 160 downriver Carson hatchery chinook returning in 1999 were readable.

A mixed model ANOVA was used to compare scale readings between smolts that had been transported and smolts that were not detected during their downstream migration. The first model estimated the difference between first ocean annulus (OA1) and ocean entry (OE) (a measure of growth in early ocean) by incorporating detection group, sex, and migration year as predictor variables. Migration year was treated as a random effect (2 out many possible years where we want to extrapolate results to any year), and group (transport and nondetect as treatment groups of interest) and sex (M,F) were treated as fixed effects. Only age 4 fish were evaluated because there was only a small proportion of the fish were 5 yrs old (<1% F, <1% M), and comparable growth could not be evaluated with 3 yr old (which were only jacks with no ocean annulus). This model suggested that based on OA1-OE measurements, fish could not be distinguished by group or sex (Table 1; Figure 1).

The same model was used to evaluate other dependent variables, which included: OA1- FA (this annulus was difficult to read and thus not a very reliable measurement); edge-OE (measure of growth from estuary to returning adults at LGR); and (OA1-OE)/edge (this variable controlled for variability in scale size, this approach was possible because we looked at the same age fish), and adult length (a direct measure of total growth). Again no significant sex or group effect were

observed for all the above dependent variables, except males were significantly longer than females as demonstrated by the significant sex effect under adult length (Table 1).

To increase the sample size in each group, the models were modified to not include sex as a predictor variable because sex was generally not a significant factor and was not identified in many of the adults and thus, excluded from the previous analyses. Again, no significant group effects were observed for estuary and early ocean growth (Table 2; Figure 1).

Another set of models was built from the previous model but included juvenile length as a covariate (ANCOVA). Smolts that were larger upon release may have had a growth advantage independent of their route of passage, adding a source of variability that may mask the group effects. By accounting for this other source of variability, a better comparison between groups may be possible. First, the assumption of homogeneity of slopes (juvenile length\*group interaction) was tested. For both groups, growth over different juvenile lengths could be described by a common slope (Table 2), and thus this assumption was met. Still no group effect was observed, although juvenile length was significant in predicting subsequent growth although in the opposite direction than was expected where smaller smolts grew faster than larger smolts (Table 2). This may have occurred because only small smolts that grew quickly survived, but slow and fast growing large smolt survived because growth was less important for large fish for several possible reasons (e.g. larger size generally results in decrease vulnerability to predators; Luecke et al. 1990). Size selective mortality may have prevented the observation of growth on smolts release at a small size because these fish did not survive to become a returning adult from which scales were collected (Post and Prankevicius, 1987).

These analyses suggest that experience in the hydrosystem did not affect the growth rate during residence in the estuary and ocean for smolts released from multiple upstream hatcheries that successfully survived to adults. Results of no significance does not equate to no true difference in stress levels, growth and ultimately survival of smolts by routes of passage. Because we are only evaluating the smolt that successfully survived to adults, size selective mortality may have masked the ability to determine if differential delayed growth effects between treatment groups truly exist.

Scales from smolt released from Carson hatchery were also measured in the same manner as described above. To make comparisons in early ocean growth between upstream and downstream stocks, a similar ANOVA model was used, but with only the fixed effects of group and sex. Year was not included in the model because only smolt tagged in the migration of 1997 comprised the only age 4 fish in the Carson hatchery group. A significant group effect and no sex effect was observed, with downriver stocks exhibiting higher growth than upriver stocks in the early ocean life stage (Table 3; Figure 3).

This significant effect may be spurious and, for the reasons previously described, may be more of a function of juvenile length. Juvenile length, however, was not available for the downstream group and, therefore, could not be factored in the model. Instead, OE was used as a surrogate to fish length upon reaching the ocean and was used as a covariate as in the previous ANCOVA model. After incorporating this variable into the model (assumption of homogeneity of slopes was met) the group effect was no longer significant (Table 4). However, OE was a significant factor, again with growth being faster for fish that previously had slower growth (presumably smaller size) to the estuary. This suggests that differences in early ocean growth were more dependent on the size of the smolts upon release at the hatcheries. The results of the ANOVA and ANCOVA models suggest that Carson smolts were released at a smaller size. Carson hatchery smolts were, in fact, smaller or exhibited slower growth before ocean entry than smolts

from upstream hatcheries (Figure 4). Models, with the same suite of dependent variables described above, were consistent with these results, except that again male were significantly longer than females as described by adult length (Tables 3 and 4).

Using multiple dependent variable models may increase the likelihood of finding a significant results based on chance alone (Type I error) and, theoretically, a MANOVA and MANCOVA approach may have been more appropriate although these approaches have their problems (Huberty and Morris 1989). Some of these models, however, were exploratory. Significant conclusions would have been based on the model considered to be the best biological representation of a legitimate comparison. Given that all these tests gave consistent non-significant results, however, strengthens, not weakens, these conclusions.

These models suggest that upstream/downstream difference could not be explained by differences in hydrosystem experience but rather to size of the smolts when entering saltwater. This comparison was consistent to the results from the comparison of transported vs. in-river migrants, where difference in growth between fish that successfully returned as adults were explained mostly by their previous growth history. Therefore, true differences in smolt growth and survival could be masked by size selective mortality.

Table 1: Summary of ANOVA models used to evaluate whether differences in post-hydrosystem growth exists between transported smolt and smolt that migrated through the hydrosystem undetected (group) and between males and females (sex).

ANOVA model		d.f.	F value	p > F
Dependent	Fixed effects			
OA1-OE	group	656	0.00	0.96
	sex	656	1.26	0.26
OA1-FWA	group	596	0.07	0.79
	sex	596	0.60	0.44
edge-OE	group	656	0.58	0.45
	sex	656	0.02	0.90
(OA1-OE)/edge	group	656	0.14	0.70
	sex	656	2.05	0.15
adult length	group	656	0.22	0.64
	sex	656	6.59	0.01
OA1-OE	group	769	0.03	0.86
OA1-FWA	group	685	0.01	0.91
edge-OE	group	769	0.41	0.53
(OA1-OE)/edge	group	698	0.86	0.35

Table 2: Summary of ANCOVA models used to evaluate whether differences in post-hydrosystem growth exists between transported smolts and smolts that migrated through the hydrosystem undetected (group) over different juvenile lengths. <sup>1</sup>The interaction between treatment and juvenile length was tested to see if the assumption of homogeneity of slopes could be met. This interaction was not significant and not included in the final model.

ANCOVA model		d.f.	F value	p > F
Dependent	Fixed effects			
OA1-OE	group	768	0.00	0.98
	juvenile length	768	7.00	0.008
	grp*juv. length <sup>1</sup>	767	0.73	0.39
OA1-FWA	group	684	0.01	0.94
	juvenile length	684	0.40	0.53
	grp*juv. length <sup>1</sup>	683	0.61	0.43
edge-OE	group	768	0.81	0.37
	juvenile length	768	9.86	0.002
	grp*juv. length <sup>1</sup>	683	0.01	0.93
(OA1-OE)/edge	group	768	0.07	0.79
	juvenile length	768	6.38	0.012
	grp*juv. length <sup>1</sup>	767	0.39	0.53

Table 3: Summary of ANOVA models used to evaluate whether differences in post-hydrosystem growth exists between downstream smolts (migrating through one dam) and upstream smolts that migrated through eight dams undetected (group) and between males and females (sex).

ANOVA model		d.f.	F value	p > F
Dependent	Fixed effects			
OA1-OE	group	485	6.67	0.01
	sex	485	1.16	0.28
edge-OE	group	485	1.46	0.16
	sex	485	4.01	0.05
(OA1-OE)/edge	group	485	13.77	0.0002
	sex	485	3.72	0.055
adult length	group	486	1.23	0.267
	sex	486	13.19	0.0003
OA1-OE	group	627	11.34	0.0008
edge-OE	group	627	9.77	0.0019
(OA1-OE)/edge	group	627	15.33	0.0001

Table 4: Summary of ANCOVA models used to evaluate whether differences in post-hydrosystem growth exists between downstream smolts (migrating through one dam) and upstream smolts that migrated through eight dams undetected (group) over different OE growth rates. <sup>1</sup>The interaction between group and OE was tested to see if the assumption of homogeneity of slopes could be met. This interaction was not significant and not included in the final model.

ANCOVA model		d.f.	F value	p > F
Dependent	Fixed effects			
OA1-OE	group	626	0.29	0.59
	OE	626	138.02	<0.0001
	grp*OE <sup>1</sup>	625	2.29	0.13
edge-OE	group	626	0.04	0.84
	OE	626	146.24	<0.0001
	grp*OE <sup>1</sup>	625	2.15	0.14
(OA1-OE)/edge	group	626	0.39	0.53
	OE	626	206.45	<0.0001
	grp*OE <sup>1</sup>	625	0.41	0.52

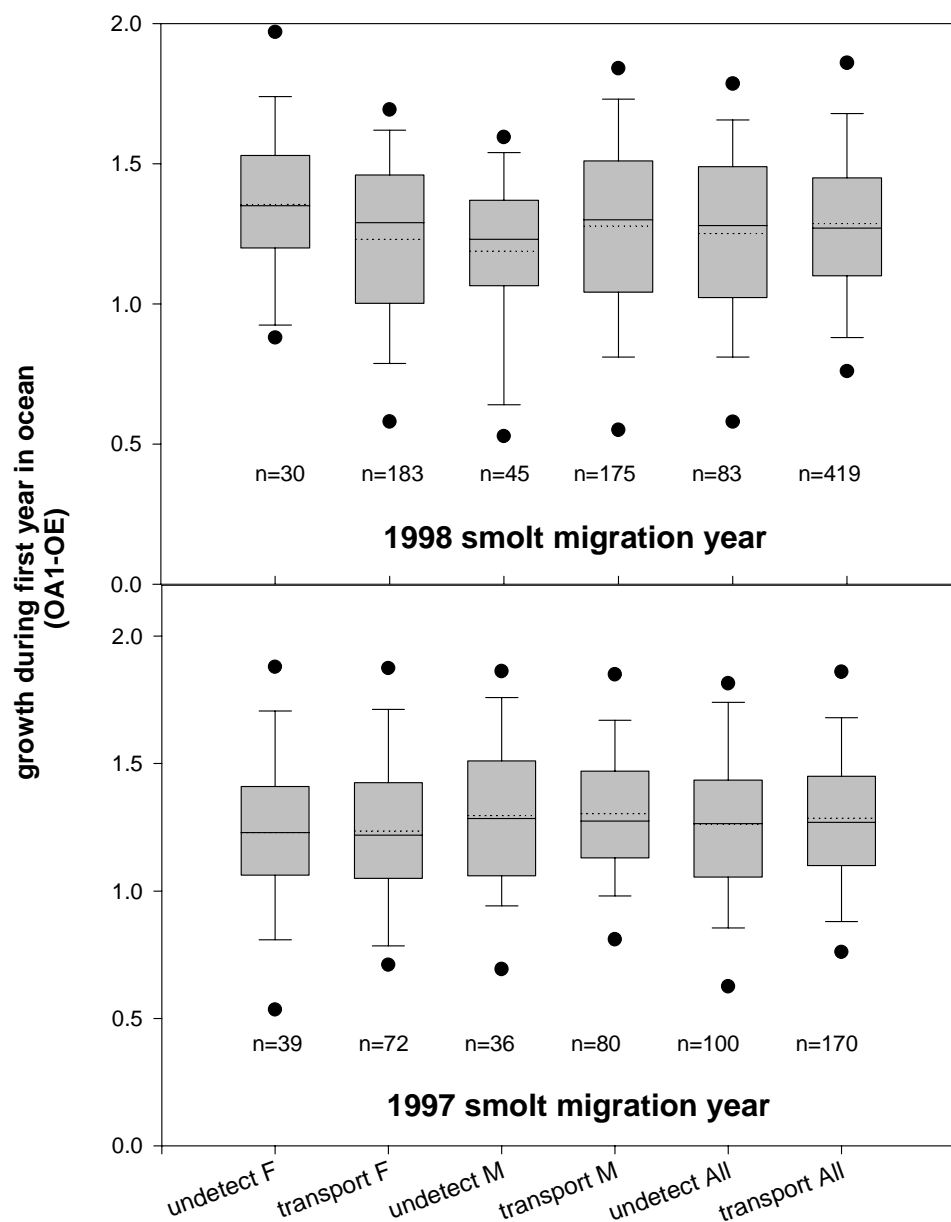


Figure 1. Distribution of growth as measured by the difference in the ocean annulus 1 (OA1) and ocean entry (OE) marks on scales collected from returning adults with smolt migration histories of undetected (undetected) and transported (transport), where F refers to females, M to males, and All for F, M, and unidentified. Box represents 25<sup>th</sup> and 75<sup>th</sup> percentiles, solid line in the box represents median, dotted line represents mean, whiskers represent 10<sup>th</sup> and 90<sup>th</sup> percentiles, and dots represent 5<sup>th</sup> and 95<sup>th</sup> percentiles.

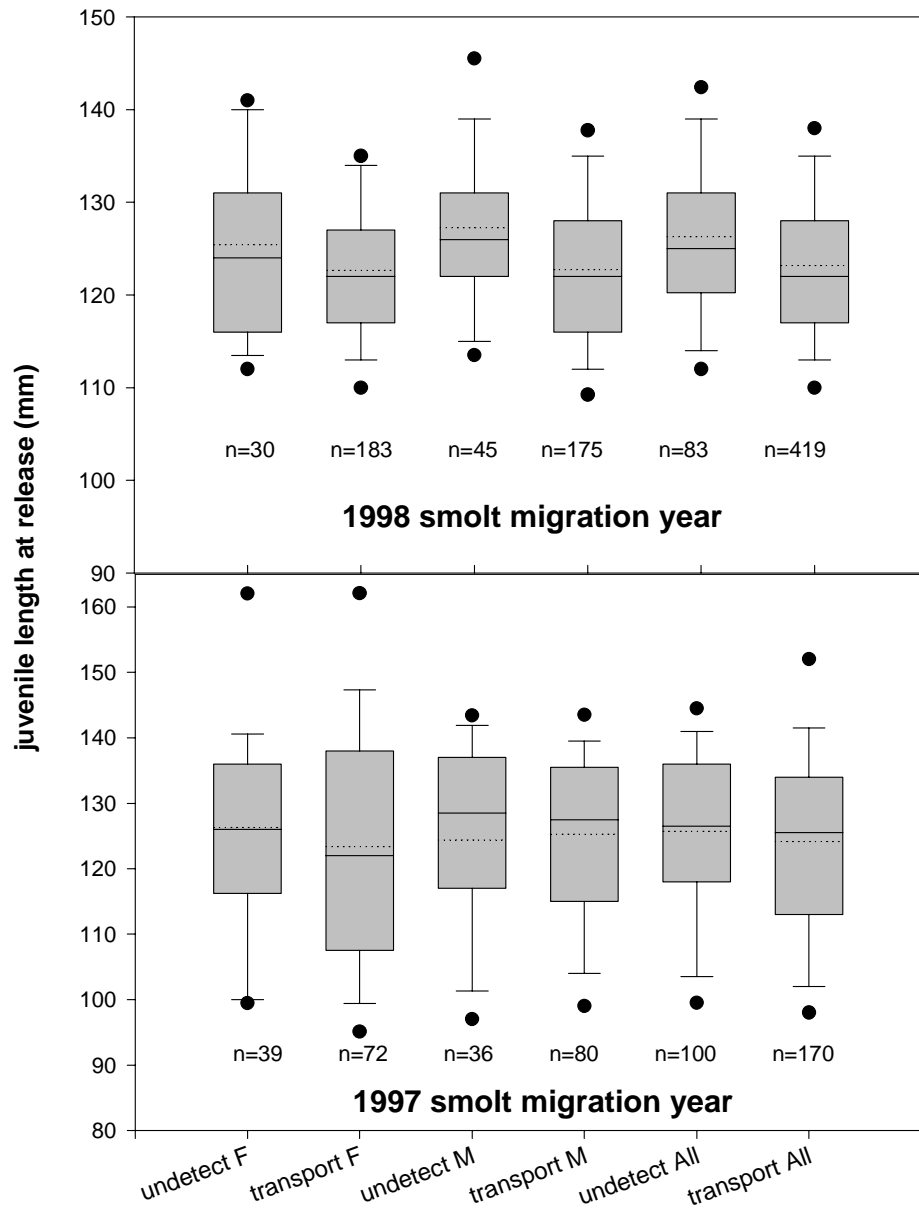


Figure 2. Distribution of juvenile lengths from returning adults with smolt migration histories of undetected (undetected) and transported (transport), where F refers to females, M to males, and All for F,M, and unidentified. Box represents 25<sup>th</sup> and 75<sup>th</sup> percentiles, solid line in the box represents median, dotted line represents mean, whiskers represent 10<sup>th</sup> and 90<sup>th</sup> percentiles, and dots represent 5<sup>th</sup> and 95<sup>th</sup> percentiles.

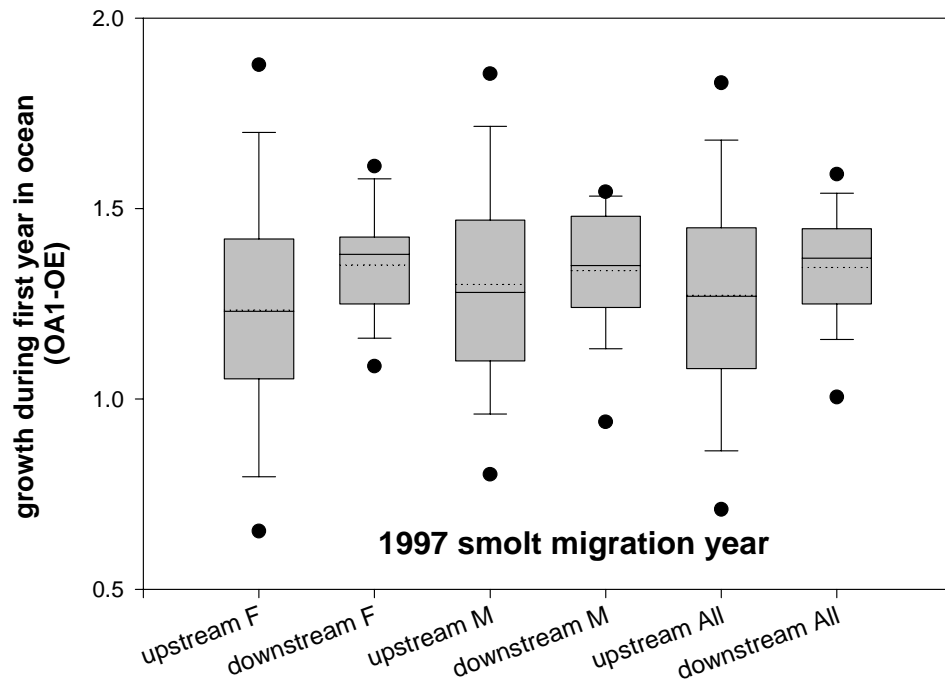


Figure 3. Distribution of growth as measured by difference between ocean annulus 1 (OA1) and ocean entry (OE) of scales collected from returning adults originating from upstream hatcheries and downstream hatcheries, where F refers to females, M to males, and All for F,M, and unidentified. Box represents 25<sup>th</sup> and 75<sup>th</sup> percentiles, solid line in the box represents median, dotted line represents mean, whiskers represent 10<sup>th</sup> and 90<sup>th</sup> percentiles, and dots represent 5<sup>th</sup> and 95<sup>th</sup> percentiles.

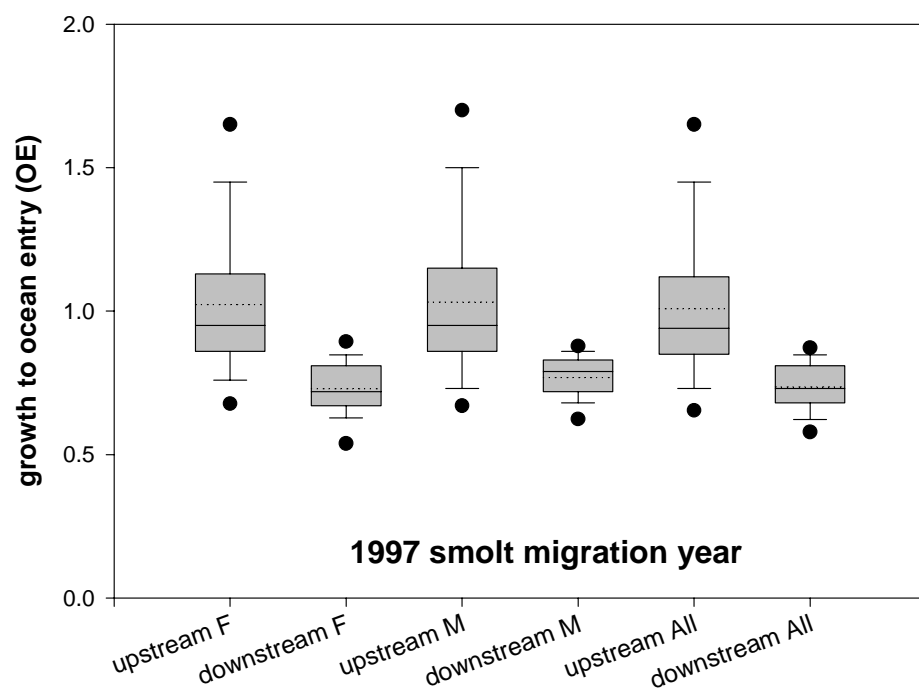


Figure 4. Distribution of growth as measured by ocean entry (OE) of scales collected from returning adults originating from upstream hatcheries and downstream hatcheries, where F refers to females, M to males, and All for F,M, and unidentified. Box represents 25<sup>th</sup> and 75<sup>th</sup> percentiles, solid line in the box represents median, dotted line represents mean, whiskers represent 10<sup>th</sup> and 90<sup>th</sup> percentiles, and dots represent 5<sup>th</sup> and 95<sup>th</sup> percentiles.

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## Appendix F

### Responses to Comments on Draft Report

This report was open for public comment for 45 days after it was released on November 30, 2001. The only comments received (see pages F-15 to F-21) were from Dr. John Skalski, University of Washington, hired to review the report by Bonneville Power Administration, on December 3, 2001. Below are the responses of the CSS Oversight Committee and FPC staff on Dr. Skalski's comments.

Dr. Skalski's two major concerns:

**1. "First and foremost, the report neglects to define how the numerators of the smolt-to-adult ratios are defined and calculated."**

Page 14 of the Status Report has a section entitled *Recovery activities at Lower Granite Dam adult trap*, which describes how adults are detected and handled at Lower Granite Dam. The section *Assignment of returning adults to categories*, is described on page 15 and states "Returning adults are assigned to groups  $T_{LGR}$ ,  $T_0$ , and  $C_1$  based on which route of passage these fish took as smolts at the Snake River dams, and whether fish on a given route were actually being transported or returned-to-river during a particular period of time." What the report neglects to state that may help clarify the above comment is that the detection rate for PIT-tagged adults at LGR is nearly 100%. Also, only PIT-tagged adults (no jacks) detected at LGR with the specific smolt detection history described in the previous sections were used in this analysis. (However, SARs including jacks is presented in one appendix table for those hatcheries where jack returns account for over 10% of the total return.)

The following paragraphs give more details on the assignment of returning adults to the various study categories. Returning adults were assigned to one of the study categories listed above by their capture disposition code. A seven digit capture disposition code was generated where the value in positions 2 (LGR), 3 (LGS), 4 (LMN), 5 (MCN), 6 (JDA), and 7 (BON) reflected what happened to an individual fish at each subsequent downstream dam. In a given position of the code, reflecting a particular dam, four possible values were available. A value of 0 indicated that the fish was not detected at that site; a value 1 indicated that the fish was detected and returned to the river at that site; a value 2 indicated that the fish was detected and "potentially" transported at that site; and a value 3 indicated that the fish had an unknown outcome (seen only on separator) at that site. Smolts that were detected as morts (most often purposely sacrificed for research purposes) at a site also received the value 3 there, but this has no effect on returning adults assignments.

In order for a returning adult to be assigned to one of the transportation categories, it had to be a first-time detected fish at the transportation site being considered, and actually transported from that site. This is because we want the PIT tag chinook to mimic their unmarked counterpart, and nearly all unmarked fish are transported when they are collected at a Snake River dam. Adults with any of the following capture disposition codes are valid transportation category fish. Category  $T_{LGR}$  contained only fish with the code of "1200000" and Category  $T_0'$  contained fish with codes of "1200000", "1020000", and "1002000" and Category  $T_0$  contained the Category  $T_0'$  fish, along with fish with code of "1000200." An example of a transported fish that is not part of the transportation category is a fish with the code "1120000" – this fish is first detected at LGR and then collected again downstream and transported at LGS. All returning adults from smolts detected at an upstream site, and later transported from a downstream site were excluded from the transportation categories. Likewise excluded from the transportation category were those fish that based on the route (coils) detected could potentially have been transported, but were subsequently detected at a downstream dam. An example of a fish detected on the coils leading to the raceways or sample room, but not transported includes fish with a code of "1020010" indicating not transported from LGS because it was detected downstream at John Day Dam (an adult with this code would be assigned to Category  $C_1$ ).

In order for a returning adult to be assigned to Category C<sub>0</sub>, it had to migrate in-river past LMN without any prior detection in a bypass system. This includes fish with the following capture disposition codes. Category C<sub>0</sub> contains returning adults with codes of “10001xy” where xy may take any combination of 0 or 1, “10003xy” where xy must have at least one value = to 1, “1000010”, “1000011”, “1000001”, and “1000000.”

In order for a returning adult to be assigned to Category C<sub>1</sub>, it had to migrate in-river past LMN with one or more prior detections in a bypass system upstream. This latter category does not reflect what is happening to the unmarked fish, it simply occurs as the result of our returning a portion of PIT tagged fish at each dam for in-river survival estimation. Category C<sub>1</sub> contains fish with the widest range of codes. All that is needed is to be detected at either LGR, LGS or LMN, and not be removed at one of these sites due to transportation, unknown final disposition, or mortality. Assigning fish to this category was the most tedious because of many capture disposition codes possible.

Returning adults not assigned to any study category included those whose migration route as smolts (transportation or in-river) was unknown because they were only detected on the separator at a Snake River dam and never detected again downstream. The returning adults with unknown disposition as smolts were not used in any analyses.

## **2a. Scientific reports are expected to and required to report confidence intervals.**

We agree that confidence intervals are imperative, however, this is a status report and as such we state that we are in the process of developing a bootstrapping procedure to estimate variance associated with T/C/ and D. We report the point estimates as point estimates of T/C and D have driven much of the management for these wild stocks. The analyses to determine the Reasonable and Prudent Alternative in the Biological Opinion, for example, use point estimates of ‘D’. We believe dealing with uncertainty in natural resource management is extremely important but at the moment we cannot get into this debate until we have developed our best estimate of variance. Dr. Skalski states that closed form analytically derived estimates of variance can be used. However, the methods that he describes does not include the sources of variance in estimating the numbers of smolt arriving at Lower Granite Dam based on detection efficiency. We believe that estimating the different variables (i.e. T/C and D) by resampling the PIT-tagged fish with replacement and calculating each step (i.e. arrival numbers at LGR, survival estimates, and SARs) over at least 1000 iterations should provide the best estimate of these variances.

## **2b. “... my [Skalski] review of their Monte Carlo methods indicates that important sources of sampling errors are being ignored, resulting in interval estimates that are too narrow.**

We initially utilized probabilistic models suggested in Dr. Skalski’s comments to estimate confidence intervals around smolt numbers in the various study categories using Monte Carlo methods, but found that it was inappropriate in that smolt numbers that were actually known, such as transported numbers at Lower Granite Dam, received wide confidence intervals. With the probabilistic models, it is as though you are standing at the hatchery and using a survival probability to Lower Granite Dam, a probability of collection, and finally a probability of transport once collected to estimate the number of smolts expected to be transported there along with an associated confidence interval [equation (b) in each category below]. However, it is more realistic to view that you are standing at Lower Granite Dam and counting the number of smolts transported. The number of smolts transported at Little Goose and Lower Monumental dams are also known counts, however, here an expansion to Lower Granite Dam equivalents requires the use of smolt survival estimates that are measured with error. The number of smolts in Category C<sub>0</sub> and C<sub>1</sub> also utilize survival parameters measured with error for estimation of smolt numbers. Since estimating the numbers of smolts in Category C<sub>0</sub> requires the most survival parameters (S<sub>1</sub>, S<sub>2</sub>, and S<sub>3</sub>) measured with error, Category C<sub>0</sub> smolt numbers receive the widest confidence intervals, which is logical. The final approach used the m<sub>12</sub>, m<sub>13</sub>, and m<sub>14</sub> as fixed counts and the

survival parameters as random variables in a Monte Carlo simulation to create a distribution of smolts for each study category [equation (a) in each category].

The number of fish alive in Lower Granite Dam tailrace that are “destined” to pass undetected at Lower Granite, Little Goose, and Lower Monumental dams are:

$$\begin{aligned} (a) \quad C_0 &= X_{000} / S_2 \cdot S_3 = R_1 \cdot S_1 - m_{12} - m_{13}/S_2 - m_{14}/(S_2 \cdot S_3) - 2\Box_0 \\ (b) \quad E(C_0) &= E(X_{000}) / (S_2 \cdot S_3), = R_1 \cdot S_1 \cdot (1 - p_2) \cdot (1 - p_3) \cdot (1 - p_4) - 2\Box_0 \end{aligned}$$

The number of fish starting at LGR “destined” for the detected in-river category (detected at least once and remaining in-river to below Lower Monumental Dam are:

$$\begin{aligned} (a) \quad C_1 &= P(U_1) \cdot m_{12} + P(U_2) \cdot m_{13}/S_2 + P(U_3) \cdot m_{14}/(S_2 \cdot S_3) - 2\Box_1 \\ (b) \quad E(C_1) &= R_1 \cdot S_1 \cdot \{ [P(U_1) \cdot p_2] + [P(U_2) \cdot (1 - p_2) \cdot p_3] + [P(U_3) \cdot (1 - p_2) \cdot (1 - p_3) \cdot p_4] \} - 2\Box_1 \end{aligned}$$

The number of fish starting at Lower Granite Dam that are “destined” for one of the three transportation sites (1=LGR; 2=LGS; and 3=LMN) are:

$$\begin{aligned} (a) \quad T_1 &= (X_{200}/m_{12}) \cdot m_{12} = P(T_1) \cdot m_{12} \\ (b) \quad E(T_1) &= R_1 \cdot S_1 \cdot [P(T_1) \cdot p_2] \\ (a) \quad T_2 &= (X_{020}/m_{13}) \cdot m_{13}/S_2 = P(T_2) \cdot m_{13}/S_2 \\ (b) \quad E(T_2) &= R_1 \cdot S_1 \cdot [P(T_2) \cdot (1 - p_2) \cdot p_3] \end{aligned}$$

$$\begin{aligned} (a) \quad T_3 &= (X_{002}/m_{14}) \cdot m_{14}/S_2 \cdot S_3 = P(T_3) \cdot m_{14}/S_2 \cdot S_3 \\ (b) \quad E(T_3) &= R_1 \cdot S_1 \cdot [P(T_3) \cdot (1 - p_2) \cdot (1 - p_3) \cdot p_4] \end{aligned}$$

The SARs computed for the various study categories are simply the parameter “p” from the respective binomial distribution where data is of the form “1” for returning adults and “0” for no returning adults out of the initial N smolts in the category. Using the expectations and variances of binomially distributed adult return data is what NMFS used in past years in their transport and control groups’ SAR confidence intervals. Although the number of returning adults is fixed once all adults from a given year class are counted, in applying the Monte Carlo simulation we view this number of adults as simply the expected number from the underlying binomial distribution, and at each iteration we randomly pick the adult count from this underlying distribution and divide them by the respective smolt numbers to create a distribution of SARs, from which the confidence interval is obtained. Under the assumptions that all the smolts are independent and identically binomially distributed with the expectation of “p” probability of survival to Lower Granite Dam as an adult, then the 95% confidence intervals determined in the draft report will provide proper coverage of the uncertainty. However, if there are groups of fish within the population with higher underlying probability of survival to adult than other groups within the population, we do not believe that the methodology being recommended by Dr. Skalski provides any better coverage of the error about the common parameter “p” being estimated.

Dr. Skalski's specific comments:

1. **Use CJS to estimate covariance.** The CJS model output from Program Mark gives the covariances directly, and these covariances are being used in the computation of the variance of the product of multiple reach survival estimates. We present the formula for using correlation and standard error estimates to generate these covariance estimates because in the appendix tables we present the respective correlation and standard error data being used. Since the table data is rounded to only six digits past the decimal for presentation purposes, we prefer to show standard errors and correlations rather than variances and covariances, since the latter statistics will have more leading zeros before any significant digits are presented.
2. **CJS expansion should incorporate reach estimate where possible, should not be arbitrary.** We agree and, in fact, this is what we did. Our report was not clear on this and has been revised to reflect this comment.

on page 7, first full paragraph change

“Therefore, the annual survival ... recapture models from LGR to LMN or MCN to the reach from LMN or MCN down to BON. We expanded the ...”

to

“Therefore, the annual survival ... recapture models from LGR to LMN, MCN, or JDA to the reach from LMN, MCN, JDA down to BON. We estimated survival to the furthest dam possible. In some cases, however, survival estimates had very large standard errors or were unidentifiable, and we then had to expand to these reaches and down to Bonneville Dam. At times a reach survival estimate was greater than 100%. This may occur if the previous reach survival estimate was too low. We did not constrain this estimate to 100% unless the standard error was greater than 10%. We did not use a reach survival estimate that had standard error greater than 25% of the estimate. We expanded the ...”

3. **How we came up with numbers of PIT-tags.** The number of PIT tagged wild chinook used in any given year was simply a function of how many wild yearling chinook happened to be PIT tagged at locations above Lower Granite Dam by all studies in that year. We had no control on that number. The number of hatchery chinook to be PIT tagged was set specifically for the CSS. For migration year 1997, the smolts were PIT tagged at the hatcheries in numbers proportional to production with the goal of having at least 43,000 PIT tagged in the transport group and 64,500 PIT tagged in the overall in-river group. These tagging goals were set to assure a minimum of 86 adults total for the aggregate of all hatcheries under conditions of historic low SARs. These quotas were set to test the significance ( $\alpha=0.05$ ,  $\beta=0.2$ ) of a 50% increase in SAR of transported over in-river migrating smolts. Starting in migration year 1998, a fixed tagging quota was established to ensure that there be adequate inclusion of all key hatcheries from each major drainage above Lower Granite Dam, because a proportional approach would cause most smolts to be tagged at only two-three hatcheries covering two drainage. Because SAR levels for chinook returning from migration years 1997 to 1999 were increasingly much higher each year than were originally expected in the planning stage, it was possible to analyze the hatchery chinook return data at the individual hatchery level.

4. **Define PA and PO better.** We have added a clearer explanation of these proportions.

On page 10, replace:

“This can be done by using the proportion of total collected (untagged and tagged) chinook smolts (composite of hatchery and wild stocks) that are transported for a given year (USACOE 1994-1998),  $PA_j$ , where  $j$  represents a collector project, to adjust the proportion of first detections that were transported relative to the total first detections at a given project,  $PO_j$ .”

**with**

“Adjusting the proportion of the PIT-tagged smolts that were transported by the proportion of the run-at-large that was actually transported at each project can correct this bias. Let  $PA_j$  represent the actual proportion of all spring/summer chinook smolt (tagged, non-tagged, hatchery, and wild) arriving at a collector project ( $j$ ) that was transported. Let,  $PO_j$  represent the proportion of the all PIT-tagged wild or hatchery (depending on the group evaluated) spring/summer chinook arriving at a collector project that was transported.”

5. **Calculate expected value of PA/PO.** This equation is simply a computational formula that theoretically weights a linear combination of site-specific SARs (one for each transport dam) by the respective total number of tagged and untagged smolts being transported at each site for a given hatchery. The following detailed write-up shows the algebraic connection between the theoretical and computation formulas, and provides insight into numbers of smolts (tagged and untagged) destined for transportation from the study hatcheries in migration years 1997-99.

#### **Weighting transportation data to create total transport aggregate**

For the transportation categories in the 2001 CSS Annual Report, hatchery chinook smolt-to-adult survival rates have been computed for LGR alone, an unweighted aggregate for the Snake River sites, and a weighted aggregate for all four transportation sites. Considering LGR alone is the simplest approach as there is no need to consider any weighting scheme and no need to expand smolt numbers to LGR equivalents (this estimated SAR is presented for hatchery chinook in both the main text and Appendix B's tables). The aggregation across dams is more involved. The initial unweighted aggregate of the Snake River sites simply involved summing all returning adults that were transported from one of the sites and dividing by the sum of the smolts transported in LGR equivalents. This method produces an unbiased estimated aggregate SAR provided the “true” SAR from each transportation site is identical (this estimated aggregate SAR is presented for hatchery chinook as Category T<sub>0</sub>' in Appendix B's tables). The unweighted aggregate may be viewed as a weighted sum of site-specific SARs where the weighting factor is simply the proportion of PIT tagged smolts transported at each site (in LGR equivalents):

$$\begin{aligned} \text{SAR}(T_0') &= \{n_{12} \cdot \text{SAR}(T_{\text{LGR}}) + (n_{13}/S_2) \cdot \text{SAR}(T_{\text{LGS}}) + (n_{14}/S_2 S_3) \cdot \text{SAR}(T_{\text{LMN}})\} / \{n_{12} + (n_{13}/S_2) + (n_{14}/S_2 S_3)\} \\ &= \{A_{\text{LGR}} + A_{\text{LGS}} + A_{\text{LMN}}\} / \{n_{12} + (n_{13}/S_2) + (n_{14}/S_2 S_3)\} \end{aligned}$$

where  $n_{1j}$ =number of first-time detected PIT tagged smolts transported at  $j^{\text{th}}$  site ( $j=2$  for LGR,  $j=3$  for LGS, and  $j=4$  for LMN);  $A_j$ =number of PIT tagged adults returning from transportation at  $j^{\text{th}}$  dam; and  $\text{SAR}(T_j)$  is ratio of PIT tagged adults returning to PIT tagged smolts transported at the  $j^{\text{th}}$  dam.

A weighted aggregate for all four transportation sites (including MCN) was computed for both the hatchery and wild chinook (it was the only approach used for the wild chinook). The weighted aggregate of the Snake River sites involved multiplying all returning transported adults and their corresponding smolt numbers (in LGR equivalents) by a site-specific ratio.

$$SAR(T_0) = \{W_1A_{LGR}+W_2A_{LGS}+W_3A_{LMN}+W_4A_{MCN}\} / \{W_1n_{12}+ W_2(n_{13}/S_2)+ W_3(n_{14}/S_2S_3)+ W_4(n_{15}/S_2S_3S_4)\}$$

where  $W_{j-1} = (t_j/C_j)/(n_{1j}/m_{1j})$  for the  $j^{th}$  site ( $j=2$  for LGR,  $j=3$  for LGS,  $j=4$  for LMN, and  $j=5$  for MCN);  $t_j$  = total number of collected yearling (sp/su/fa) chinook smolts transported;  $C_j$  = total collection of yearling (sp/su/fa) chinook smolts;  $n_{1j}$  = number of first-time detected PIT tagged yearling (sp/su) chinook smolts transported; and  $m_{1j}$  = number of first-time detected PIT tagged yearling (sp/su) chinook collected.

This weight is the estimated proportion of total collected smolts transported divided by the estimate of PIT tagged smolts transported in LGR equivalents. This weight adjusts for the under representation of PIT tagged smolts in transportation compared to the unmarked population of collected smolts. The estimated proportion of the total (tagged and untagged) collected smolts transported was obtained for the draft report by simply taking the proportion transported of the total combined hatchery and wild chinook collection number for a given transportation facility. This number includes the total combination of wild spring/summer and hatchery spring/summer/fall yearling chinook of Snake River origin at all transportation facilities, plus the wild and hatchery spring/summer yearling chinook of Mid-Columbia River origin at MCN. Ideally the weight would be based on the same fish as the group being estimated, that is wild spring/summer Snake River basin chinook and the hatchery specific hatchery chinook, however, there is no way to assign the unmarked fish to their respective group. Therefore, we make the assumption that the transportation proportion for the unmarked population of each specific hatchery group and the aggregate wild group is approximately the same.

In each year of study from 1994 to 2000, with the exception of 1997, nearly all (>90%) first-time collected smolts at LGR, LGS, and LMN were transported. Only when equipment failures or lack of barge space occurred were untagged smolts returned to the river. In 1997, during the peak of the steelhead run, first all B-side bypass flume fish, and later all fish were returned to the river at LGS and LMN, lowering the percent of collected smolts transported to around 50%. Following nearly 100% transportation at MCN in 1994, the transportation of springtime migrating smolts was curtailed during the 1995 through 2000 migration years until into June when subyearling chinook predominate in the run. This operation resulted in only between 0.2 and 6.0% of the late migrating yearling chinook run being transported in those years.

For the hatchery CSS smolts, the preferred approach is to consider that the SARs for smolts transported from different dams may vary and compute a weighted sum of site-specific SARs where the weighting factor is the proportion of all smolts (PIT tagged smolts and unmarked smolts) transported (in LGR equivalents) from the  $j^{th}$  dam for the  $h^{th}$  hatchery. Because we do not have a measure of the tagging proportion of wild stocks, a modified approach will be illustrated later. For the  $h^{th}$  hatchery, the tagging proportion at the hatchery is number of PIT tagged fish released ( $R_h$ ) divided by hatchery production release ( $N_h$ ). Under the assumption that PIT tagged and untagged smolts have the same probability of surviving to and being collected at the dams in the hydro system, the following relations are true:

Number of first-time collected  $h^{th}$  hatchery smolts at Lower Granite Dam equals

$$\begin{aligned} R_h \cdot S_1 \cdot p_2 &= m_{12h} \text{ for tagged fish} \\ N_h \cdot S_1 \cdot p_2 &= C_{2h} \text{ for total tagged and untagged fish} \\ \lambda_h &= R_h/N_h = m_{12h}/C_{2h} \text{ for tagging proportion} \end{aligned}$$

Number of first-time collected  $h^{th}$  hatchery smolts at Little Goose Dam equals

$$\begin{aligned} R_h \cdot S_1 \cdot (1-p_2) \cdot S_2 \cdot p_3 &= m_{13h} \text{ for tagged fish} \\ N_h \cdot S_1 \cdot (1-p_2) \cdot S_2 \cdot p_3 &= C_{3h} \text{ for total tagged and untagged fish} \\ \lambda_h &= R_h/N_h = m_{13h}/C_{3h} \text{ for tagging proportion} \end{aligned}$$

Number of first-time collected  $h^{th}$  hatchery smolts at Lower Monumental Dam equals

$$R_h \cdot S_1 \cdot (1-p_2) \cdot S_2 \cdot (1-p_3) \cdot S_3 \cdot p_4 = m_{14h} \text{ for tagged fish}$$

$$N_h \cdot S_1 \cdot (1-p_2) \cdot S_2 \cdot (1-p_3) \cdot S_3 \cdot p_4 = C_{4h} \text{ for total tagged and untagged fish}$$

$$\lambda_h = R_h/N_h = m_{14h}/C_{4h} \text{ for tagging proportion}$$

Number of first-time collected  $h^{th}$  hatchery smolts at McNary Dam equals

$$R_h \cdot S_1 \cdot (1-p_2) \cdot S_2 \cdot (1-p_3) \cdot S_3 \cdot (1-p_4) \cdot S_4 \cdot p_5 = m_{15h} \text{ for tagged fish}$$

$$N_h \cdot S_1 \cdot (1-p_2) \cdot S_2 \cdot (1-p_3) \cdot S_3 \cdot (1-p_4) \cdot S_4 \cdot p_5 = C_{5h} \text{ for total tagged and untagged fish}$$

$$\lambda_h = R_h/N_h = m_{15h}/C_{5h} \text{ for tagging proportion}$$

From the weighting factor  $W_{j-1} = (t_j/C_j)/(n_{1j}/m_{1j})$  used on PIT tagged wild and hatchery chinook, we will show that the preferred approach of weighting site-specific SAR's by  $t_{jh}$  can be achieved for the individual hatchery groups. By adding a subscript  $h$  to represent an individual hatchery and rearranging terms in the relation  $W_{(j-1)h} = (t_{jh}/C_{jh})/(n_{1jh}/m_{1jh})$  to solve for  $t_j$ , we obtain the following equality ( $j=2$  for LGR,  $j=3$  for LGS,  $j=4$  for LMN, and  $j=5$  for MCN):

$$t_{jh} = [(W_{(j-1)h})(n_{1jh}) \cdot (C_{jh})]/(m_{1jh})$$

$$t_{jh} = [(W_{(j-1)h})(n_{1jh})]/\lambda_h$$

The quantity in brackets  $[(W_{(j-1)h})(n_{1jh})]$  adjusts the number of PIT tagged smolts for hatchery  $h$  being transported to the level expected had the PIT tag transport proportion equaled the total (tagged and untagged) transport proportion, while the factor  $\lambda_h$  expands the transport number to total tagged and untagged smolts for hatchery  $h$ . The weights  $t_{jh}$  are applied directly to the site-specific SAR's to give the following:

$$SAR(T_0) = \{t_2 \cdot SAR(T_{LGR}) + (t_3/S_2) \cdot SAR(T_{LGS}) + (t_4/S_2S_3) \cdot SAR(T_{LMN}) + (t_5/S_2S_3S_4) \cdot SAR(T_{MCN})\} / \{t_2 + (t_3/S_2) + (t_4/S_2S_3) + (t_5/S_2S_3S_4)\}$$

Substituting the equality  $t_{jh} = [(W_{(j-1)h})(n_{1jh})]/\lambda_h$  into the  $SAR(T_0)$  equation, simplifying terms, and multiplying by  $\{(1/\Sigma W_i)/(1/\Sigma W_i)\}$  produces the computational equation 3 given on page 11 of the 2001 CSS Annual Report:

$$SAR(T_0) = \{[W_1A_{LGR} + W_2A_{LGS} + W_3A_{LMN} + W_4A_{MCN}]/\Sigma W_i\} / \{[W_1n_{12} + W_2(n_{13}/S_2) + W_3(n_{14}/S_2S_3) + W_4(n_{15}/S_2S_3S_4)]/\Sigma W_i\}$$

When applying the computation equation, we are in theory weighting a linear combination of site-specific SAR's by the respective total proportion of tagged and untagged smolts being transported at each site (in LGR equivalents) for a given hatchery. Another way to view this is by considering the total population of  $h^{th}$  hatchery smolts (tagged and untagged) that are alive at LGR in the transportation category as being partitioned into four strata, one for each dam, with the number of smolts "destined for transportation" at a particular dam being placed into the stratum for that dam. A fish "destined for transport" could still die before arriving at a downstream transportation site or, if tagged, could still be returned to the river for survival estimation purposes. However, whether tagged or untagged, the probability of transport remains the same in the case of a fish "destined for transport." Table 1 shows the estimated number of smolts in each stratum for which a site-specific SAR (Table 2) is, in theory, being computed when we are using the computation equation above.

**Table 1. Estimated number of chinook smolts (tagged and untagged) from each CSS hatchery “destined for transportation” at each dam in 1997 to 1999.**

Year	Dam	RAPH	MCCA	DWOR	IMNH	LOOH	PAHP
1997	LGR	11,420	33,813	10,965	9,948	29,254	21,928
	LGS	3,744	11,434	4,655	3,845	10,807	6,353
	LMN	2,566	6,257	2,946	2,399	7,650	3,504
	MCN	0	0	101	76	0	142
1998	LGR	283,813	101,471	293,340	25,608	94,366	
	LGS	142,449	59,345	192,837	17,576	49,370	
	LMN	67,803	30,692	97,284	7,447	22,198	
	MCN	0	186	2,609	0	0	
1999	LGR	566,498	152,200	138,994	25,873	46,348	
	LGS	827,674	280,284	363,431	51,978	90,093	
	LMN	260,329	99,861	139,237	15,250	29,900	
	MCN	0	0	0	0	0	

**Table 2. Number of PIT tagged returning adults (in parenthesis) and estimated site-specific SAR's corresponding to the total (tagged and untagged) smolt numbers presented in Table 1 for 1997 to 1999.**

Year	Dam	RAPH	MCCA	DWOR	IMNH	LOOH	PAHP
1997	LGR	0.80% (33)	1.48% (87)	0.85% (19)	1.20% (25)	0.36% (22)	0.39% (19)
	LGS	0% (0)	2.67% (3)	0% (0)	0% (0)	0.82% (1)	0% (0)
	LMN	2.04% (1)	2.66% (1)	0% (0)	0% (0)	0% (0)	0% (0)
	MCN	N/A	N/A	0% (0)	0% (0)	N/A	0% (0)
1998	LGR	2.12% (239)	2.90% (262)	0.99% (110)	0.91% (37)	0.45% (49)	
	LGS	1.18% (16)	0.99% (9)	0.66% (22)	0.67% (4)	0.17% (3)	
	LMN	0.86% (2)	0.53% (1)	0% (0)	0% (0)	1.63% (3)	
	MCN	N/A	0% (0)	0% (0)	N/A	N/A	
1999	LGR	3.12% (231)	3.82% (182)	1.16% (57)	2.98% (65)	0.77% (40)	
	LGS	2.81% (145)	2.44% (136)	1.08% (47)	1.93% (49)	0.61% (3)	
	LMN	0.91% (3)	2.91 (7)	0.52% (3)	2.31% (3)	0.66% (2)	
	MCN	N/A	N/A	N/A	N/A	N/A	

The SAR for Category T<sub>0</sub> fish is meant to provide an overall survival rate for yearling chinook experiencing the LGR-LGS-LMN-MCN transportation program. The data in Tables 1 and 2 demonstrate the difficulty in obtaining site-specific SAR values if not enough smolts are transported at each site where an estimate is desired. Starting in migration year 2000, we have increased the numbers of study fish transported at LGS and LMN in order to improve our estimation of the Category T<sub>0</sub> SAR. By improving our ability to obtain site-specific SAR's, we in turn are improving the accuracy of the overall SAR for Category T<sub>0</sub>. It is apparent from these tables that especially in 1997, differences in SAR's between Category T<sub>LGR</sub> and Category T<sub>0</sub> may

be resulted in part from few adult returns from insufficient numbers of CSS PIT tagged smolts being transported at LGS, LMN, and MCN.

6. **Define adult numbers.** The number of adults in each study category is obtained using the capture disposition information on the returning adults. This procedure has been detailed earlier in our response to Dr. Skalski's first major concern.
7. **Definition of  $C_1$  is not correct, this is definition of first time detects at Snake River sites.** The definition and formula for the Category  $C_1$  fish on page 13 is correct. On lines 10-12 of page 13 we define this category, stating "We refer to this group as the  $C_1$  group, which consists of PIT tagged smolts detected at one or more of the Snake River collector dams (LGR, LGS, or LMN) and continue to migrate in-river below LMN." On the previous line 9 we ambiguously state "... detected one or more times while migrating through the hydro system..." when we should have said "**... detected one or more times while migrating through the Snake River hydro system ...**" We will make this correction on page 13. We are defining the categories to closely mimic what is happening to the untagged population. From 1995 to 2000, since there has not been a springtime transportation operation at McNary Dam (only late migrating yearling chinook are transported from McNary Dam after the summer transportation program begins), most collected untagged smolts are removed for transportation at a Snake River site. Therefore, PIT tagged yearling chinook that pass Lower Granite, Little Goose, and Lower Monumental dams undetected are closely mimicking the fate of untagged smolts that remain in-river below Lower Monumental Dam. With the exception of times when entire raceways of fish are returned to the river due to operational problems, lack of barge space or equipment malfunctions, the returning of PIT tagged yearling chinook at the collector dams for survival estimation purposes does not mimic the untagged population. For either of these categories, how the smolts pass the downstream Columbia River dams is immaterial to their group classification. It should be noted that the  $T_j$  for the  $j^{\text{th}}$  site covers more than just the transported fish. It should cover the number of fish removed at the  $j^{\text{th}}$  site regardless of prior capture history (includes transported fish, site-specific mortalities, and unknown disposition fish).
8. **Underestimate CI with Monte Carlo.** See our response to Dr. Skalski's second major concern listed above under item 2b.
9. **SAR CIs, must be corrected as above.** See our response to Dr. Skalski's second major concern listed above under item 2b.
10. **Hats should be used for estimates.** All of the survival parameters shown in formulas on pages 6, 11, 12, and 13 are estimates, and we have bolded these parameters to show that they are estimated. A "hat" over a parameter symbol to denote it as an estimate is important in mathematical texts where confusion would otherwise exist between formulas of population parameters and the associated formulas of the estimators of those population parameters. We do not feel that this is the case in the CSS report. However, in the box table showing the definitions of symbols, we have added the word "estimated" in front of the word survival for the  $S_2$  and  $S_3$  parameters, as was already done with the  $S_1$  parameter. In addition, we are adding the  $S_4$  parameter to cover "estimated survival from Lower Monumental Dam tailrace to McNary Dam tailrace."
11. **Must report SE and CI.** See our responses to Dr. Skalski's second major concern listed above under item 2a. We are developing a bootstrap approach that we believe will properly take care of all sources of variability.

**12. Why use geomean for yearly estimates and arithmetic mean for across hatcheries.** We have provided clarification in the text. Add after first paragraph in section LGR-LGR SARs for transported and in-river migrating fish (page 20):

“In Tables 5, 8 and 9, we are using the geometric mean as a measure of central tendency across years because Peterman (1981) showed that the distribution of SARs across years tend to be lognormally distributed. To estimate the average SAR across the different hatcheries, we are using an arithmetic mean because we do not expect this to be lognormally distributed. We could not accurately test the shape of the distribution with six hatcheries. A weighted average may also be useful to estimate the average SAR for the total hatchery production, since some hatcheries have higher production and would have more of an influence on the mean SAR (see Appendix F Response #12 on creation of annual weighted average SARs).”

Peterman, R.M. 1981. Form of random variation in salmon smolt-to-adult relations and its influence on production estimates. Can. J. Fish. Aquat. Sci. 38:1113-1119.

Creation of annual weighted average SARs for Categories  $C_0$ ,  $C_1$ ,  $T_0$ , and  $T_{LGR}$  from the set of hatchery SAR's

In order to summarize the hatchery chinook SAR data in a similar fashion to the wild chinook SAR data, an annual SAR estimate was obtained for the aggregate of the hatchery groups. For the same reasons that weighting was needed in the estimation of the Category  $T_0$  to reflected the magnitude of transportation occurring at each dam, there is the need for weighting to reflect the magnitude of each hatchery in the final aggregated group. For the CSS hatchery chinook groups, the sum of the estimated number of tagged and untagged smolts “destined for transportation” at each dam provides the preferred weighting factor for Category  $T_0$  fish (and simply weight  $t_{2h}$  for the  $T_{LGR}$  fish). For Categories  $C_0$  and  $C_1$  fish, the estimated number of tagged and untagged smolts “destined to migrate in-river” to LMN tailrace, undetected and detected, respectively, are divided by the hatchery-specific factor  $\lambda_h$  to produce the preferred weighting factor. The concept of “destined to ...” is taken into account through the expansion of smolt numbers into LGR equivalents.

The result of using weights will make the mean SAR of the aggregate of hatchery chinook be more closely comparable to that of wild chinook, since wild chinook are simply analyzed from the start as an aggregate group. In the 2001 CSS Annual Report (page 16), the breakdown of wild stocks PIT tagged show 49.1% from the Salmon River basin, 18.7% from the Grande Ronde River basin, 18.6% from the Clearwater River basin, 10.7% from the Imnaha River basin, and 3.0% tagged in the mainstem Snake River at Lewiston (mixture of basins). This spread across basins helps ensure that the PIT tagged wild chinook in the population at Lower Granite Dam fairly well represents the total population of wild chinook there. However, since the PIT tagging effort for hatchery chinook stocks was set to meet a quota beginning in 1998 and later years rather than set proportion at hatchery release, the resulting distribution of stocks within the aggregate of PIT tagged chinook at Lower Granite Dam will differ from that of the untagged fish. The result of weighting the individual hatchery SAR's in the estimation of the overall aggregate mean SAR is presented in Tables 3 to 6 for Categories  $T_0$ ,  $T_{LGR}$ ,  $C_0$ , and  $C_1$ , respectively. The aggregate mean SAR's for hatchery chinook presented in the 2001 CSS Annual Report are unweighted arithmetic means. Our goal will be to use a weighting approach in subsequent CSS reports.

**Table 3. Aggregate SAR's for hatchery chinook in Category T<sub>0</sub>.**

Year	1997		1998		1999	
	Weight t <sub>h</sub>	SAR(T <sub>0</sub> )	Weight t <sub>h</sub>	SAR(T <sub>0</sub> )	Weight t <sub>h</sub>	SAR(T <sub>0</sub> )
Rapid River H	17,730	0.0081	494,065	0.0168	1,654,501	0.0262
McCall H	51,504	0.0189	191,508	0.0192	532,345	0.0293
Dworshak H	18,566	0.0051	583,461	0.0071	641,662	0.0098
Imnaha H	16,192	0.0073	50,631	0.0069	93,101	0.0228
Lookingglass H	47,711	0.0041	165,934	0.0053	166,341	0.0066
Pahsimeroi H	31,785	0.0027				
Total	183,488		1,485,599		3,087,950	
Weighted mean		0.0088		0.0116		0.0221
Unweighted mean		0.0077		0.0110		0.0189

**Table 4. Aggregate SAR's for hatchery chinook in Category T<sub>LGR</sub>.**

Year	1997		1998		1999	
	Weight t <sub>h</sub>	SAR(T <sub>LGR</sub> )	Weight t <sub>h</sub>	SAR(T <sub>LGR</sub> )	Weight t <sub>h</sub>	SAR(T <sub>LGR</sub> )
Rapid River H	11,420	0.0081	283,813	0.0212	566,498	0.0312
McCall H	33,813	0.0148	101,471	0.0290	152,200	0.0382
Dworshak H	10,965	0.0085	293,340	0.0099	138,994	0.0116
Imnaha H	9,948	0.0120	25,608	0.0091	25,873	0.0298
Lookingglass H	29,254	0.0036	94,366	0.0045	46,348	0.0077
Pahsimeroi H	21,928	0.0039				
Total	117,328		798,598		929,913	
Weighted mean		0.0085		0.0157		0.0282
Unweighted mean		0.0085		0.0147		0.0237

**Table 5. Aggregate SAR's for hatchery chinook in Category C<sub>0</sub>.**

Year	1997		1998		1999	
	Weight c <sub>h</sub>	SAR(C <sub>0</sub> )	Weight c <sub>h</sub>	SAR(C <sub>0</sub> )	Weight c <sub>h</sub>	SAR(C <sub>0</sub> )
Rapid River H	8,851	0.0045	80,204	0.0123	425,952	0.0217
McCall H	30,648	0.0109	32,055	0.0138	198,262	0.0200
Dworshak H	11,688	0.0043	214,388	0.0132	228,493	0.0103
Imnaha H	8,444	0.0086	9,000	0.0057	26,664	0.0132
Lookingglass H	24,344	0.0058	33,988	0.0014	33,462	0.0059
Pahsimeroi H	14,661	0.0021				
Total	98,636		369,635		912,833	
Weighted mean		0.0068		0.0118		0.0177
Unweighted mean		0.0060		0.0093		0.0142

**Table 6. Aggregate SAR's for hatchery chinook in Category C<sub>1</sub>.**

Year	1997		1998		1999	
	Weight c <sub>h</sub>	SAR(C <sub>1</sub> )	Weight c <sub>h</sub>	SAR(C <sub>1</sub> )	Weight c <sub>h</sub>	SAR(C <sub>1</sub> )
Rapid River H	14,546	0.0052	254,174	0.0066	864,464	0.0156
McCall H	42,103	0.0109	107,196	0.0073	272,976	0.0171
Dworshak H	17,356	0.0031	276,694	0.0087	419,803	0.0084
Imnaha H	14,429	0.0069	28,333	0.0031	47,396	0.0114
Lookingglass H	42,719	0.0035	80,949	0.0015	124,821	0.0054
Pahsimeroi H	23,669	0.0012				
Total	154,822		747,346		1,729,460	
Weighted mean		0.0056		0.0068		0.0132
Unweighted mean		0.0051		0.0054		0.0116

The ratios of key SAR's in Table 7 of the 2001 CSS Annual Report have a geomean across hatcheries computed to represent the aggregate hatcheries. Alternatively, the weighted SAR's of the aggregate hatcheries could be used in the estimation of these ratios as shown in Table 7. The greatest difference between the weighted and unweighted approaches is seen in 1998 where Lookingglass Hatchery had a very high transportation SAR and second smallest population size (tagged and untagged) in each category and Dworshak Hatchery had the lowest transportation SAR and the largest population size (tagged and untagged) in each category. When attempting to make the hatchery aggregate results more comparable to the already aggregated wild smolts, the use of the weighting approach will be preferred.

**Table 7. Ratios of aggregate hatcheries SAR's for weighted aggregates, weighted  $\ln$  transformed aggregates, and unweighted  $\ln$  transformed (geomean) aggregates.**

Aggregation Method	Year	$T_{lgr}/T_0$	$C_1/C_0$	$T_{lgr}/C_0$	$T_0/C_0$
Weighted untransformed	1997	0.97	0.82	1.25	1.29
	1998	1.35	0.57	1.32	0.98
	1999	1.27	0.75	1.60	1.25
Weighted $\ln$ transformed	1997	1.07	0.74	1.20	1.12
	1998	1.31	0.59	1.29	0.99
	1999	1.29	0.75	1.55	1.21
Unweighted $\ln$ transformed (geomean)	1997	1.18	0.78	1.40	1.18
	1998	1.24	0.64	1.70	1.36
	1999	1.23	0.83	1.56	1.27

In the weighted versus unweighted approaches, the greatest difference stems from the differences in proportion of the hatchery population being tagged across the hatcheries since 1997 when we dropped attempting to tag proportional to production (Table 8). We needed to go to the fixed quota approach in tagging because production levels could differ by as much as 10-fold between hatcheries. Without weighting the SAR's, we are over-emphasizing the influence of Imnaha and Lookingglass hatcheries in the aggregate hatchery population at Lower Granite Dam. Also, as the production (and supplementation) releases from hatcheries not included in the CSS tagging increases (as has been seen from 1997 to 1999 [Table 8]), there will be more untagged smolts in the "complete" aggregate of hatchery chinook arriving at Lower Granite Dam than we account for in our expansions. An additional 4.2 million hatchery chinook were released into the Clearwater River basin in 1999 at acclimation ponds and hatchery sites not monitored by the CSS (plus another 1.1 million in the other basins above LGR), and it is unknown what proportion of these fish survive to LGR. The inferences we make to the aggregate hatchery chinook run-at-large assume that the aggregate of the hatcheries we monitor is reflective of those hatcheries that we do not monitor.

**Table 8. Proportion (factor  $\lambda_h$ ) of hatchery population PIT tagged for CSS in 1997-99.**

Year	RAPH	MCCA	DWOR	IMNH	LOOH	PAHP	CSS proportion of total basin hatcheries
1997	0.472	0.221	0.261	0.263	0.261	0.286	0.921
1998	0.054	0.120	0.049	0.213	0.150		0.721
1999	0.017	0.042	0.046	0.108	0.143		0.509

**13. Unclear how values were determined in Table 7. Clarification is required! Use ratio instead of % in comparing wild to hatchery.** The intention of this table is to describe the

adequacy of using hatchery fish as a surrogate for wild fish. We choose to use percent difference between hatchery and wild fish as a measure of this adequacy. Ratio could be used for the same purpose as described by Dr. Skalski. We have added this equation for clarification.

add as footnote to Table 2 and Table 7.

“The percent difference of wild fish relative to hatchery fish is express as  $(\theta_{\text{wild}}/\theta_{\text{hatchery}} - 1) * 100\%$  where  $\theta$  represents the variable of interest ...”

**14. Table 9 should use SAR<sub>T0</sub>/SAR<sub>C0</sub> instead of T<sub>0</sub>/C<sub>0</sub>.** Because “T/I” (transport/in-river) and “D” (delayed mortality) are well-established terms used throughout the region to represent these ratios, we have chosen to keep with this naming convention. The table legends explain in detail what the different terms represent. Actually if we want to be more specific we should use LGR-LGR SAR<sub>T0</sub>/LGR-LGR SAR<sub>C0</sub> for T<sub>0</sub>/C<sub>0</sub> and BON-LGR SAR<sub>T0</sub>/BON-LGR SAR<sub>C0</sub> for D.

**15. Should not exclude 1994.** We agree that when estimating an overall T/I ratio or D value we should not leave out 1994 value simply because it is well above any values seen since then. We have added rationale of why 1994 was included and excluded in overall estimates of T/I and D.

add before Arrival Numbers at LGR section:

“For wild fish we have reported the mean SAR, T/I, and D values between 1994-1999 and between 1995-1999. We believe that 1994 does not represents the current values under the Reasonable and Prudent Alternative (RPA) because this year was before implementation of the 1995 Biological Opinion RPA that calls for a spill and flow program to assist in-river migration. Analyses for the 2000 Biological Opinion used past years values to give an indication how the proposed RPA operations (same as 1995 RPA for spill and flow requirements) would affect the downstream migration. Because minimal spill was implemented in 1994, the majority of all non-detected in-river migrating spring/summer chinook had to pass all the projects through the turbines. Passing the dams through the turbines rather than over the spillway is thought to be a more stressful route of passage. This would likely result in higher delayed mortality of in-river migrants than has occurred since the spill program has been implemented. This is corroborated by D values approximately twice as high as has been observed since spill has been implemented. We do not believe that 1994 is representative of the intentions of the 1995 or 2000 RPA. However, the analyses used in the 2000 Biological Opinion did use the 1994 D value in the their overall geometric mean D value despite the fact that the hydro system in 1994 was not operated under the RPA they were trying to characterize. For these reasons, we report T/I and D values with and without 1994.”

# UNIVERSITY OF WASHINGTON

December 3, 2001

Ms. Michele DeHart  
Fish Passage Center  
2501 SW First Ave., Suite 230  
Portland, Oregon 97201-4752

Dear Ms. DeHart:

This letter constitutes a technical review of the report entitled,

“Comparative survival study (CSS) of PIT tagged spring/summer chinook:  
Status report for migration years 1997-2000 mark/recapture activities.”

The report addresses crucial issues of the benefits of transportation and the relative survival of wild and hatchery smolt in the Snake/Columbia River system. Key information on the processes influencing outmigration success may come from the results of this study. Specific comments are attached. However, I have two general comments that apply to the technical report.

First and foremost, the report neglects to define how the numerators of the smolt-to-adult ratios (SAR) are defined or calculated. The report provides reasonable detail on the definitions of the smolt classes (i.e.,  $T_{1gr}$ ,  $T_0$ ,  $C_0$ , and  $C_1$ ). However, nowhere are the definitions and associated calculations of the numerators (i.e., adult returns) for the SARs provided. It is impossible to determine the validity of the SAR estimates without the adult calculations provided. Without confirmation of the SAR calculations, it is also impossible to determine the validity of the T/C ratios (i.e., transportation benefit ratios) or the D-values. These omissions need to be rectified and the methods reevaluated before the final draft of the report is submitted.

An earlier review of Berggren and Basham (2000) entitled “Comparative survival rate study (CSS) of hatchery PIT-tagged chinook, status report for migration years 1996-1998” found problems in the proposed evaluation of SARs and T/C ratios (see attached copy). It is not possible to ascertain whether the analytical deficiencies noted earlier have been rectified or simply ignored.

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Secondly, as a scientific report, measures of sampling error associated with the parameter estimates is expected and required. The authors acknowledge they are working on confidence interval (CI) calculations for the final report. However, my review of their Monte Carlo methods indicates that important sources of sampling errors are being ignored, resulting in interval estimates that are too narrow. In many (and perhaps all) circumstances, closed-form analytically derived variance formula could be produced to replace or support the Monte Carlo procedures. I recommend such method be used to validate the computer simulation results. The two methods should provide CIs of the same relative size, and if different, the Monte Carlo methods should produce intervals  $\geq$  analytic methods if all is correct.

### Specific Comments

Page 6, Equation (1). It should be noted Meyer's formula is a Taylor series approximation (i.e., delta method) for the true variance of a product of correlated random variables. The covariance between  $\hat{S}_2$  and  $\hat{S}_1$  [i.e.,  $\text{Cov}(\hat{S}_2, \hat{S}_3)$ ] can be obtained directly from the Cormack-Jolly-Seber (CJS) model without the need for the intermediate calculation of  $\text{Cov}(\hat{S}_2, \hat{S}_3) = \text{SE}(\hat{S}_2) \cdot \text{SE}(\hat{S}_3) \cdot \text{Correlation}(\hat{S}_2, \hat{S}_3)$ .

Page 7, first paragraph. Estimates of survival from Lower Granite to Bonneville were calculated by expanding the per mile survival rate calculated for smolts in either of the following reaches ; (a) Lower Granite – Lower Monumental or (b) Lower Granite – McNary. The CJS models will provide survival estimates from release to John Day Dam. It would seem most appropriate to make the expansion based on information for the largest reach possible, i.e., Lower Granite – John Day. In this way, the extrapolation is the least model-dependent, representing the majority of the reach of inference. Furthermore, the reach selected for expansion should be standardized and not left to arbitrary selection.

Page 8, last paragraph. The study was designed to include a minimum of 43,000 transport and 64,500 inriver PIT-tagged smolts in order to provide a minimum of 86 returning adults. However, what level of precision for an SAR or T/C ratio is anticipated from these levels of tagging and return?

Page 10, last paragraph. Definitions of  $PA_j$  and  $P0_j$  need to be more clearly defined in terms of what proportions they represent (i.e., numerator and denominator).

Page 11, Equation (2). The expected value of the ratio  $PA_j / P0_j$  needs to be calculated to justify it as a weight.

Page 15, last paragraph. The T/C ratio or transport benefit ratio is defined as

$$\text{T/C Ratio} = \frac{\text{SAR}_T}{\text{SAR}_C}$$

which, in turn, can be expressed as

$$\text{T/C Ratio} = \frac{\left(\frac{t}{T}\right)}{\left(\frac{c}{C}\right)}.$$

Two different definitions of  $T$  (i.e.,  $T_{1gr}$  and  $T_0$ ) and of  $C$  (e.g.,  $C_0$  and  $C_1$ ) were provided for their smolt numbers. However, no comparable definitions for the returning adult  $t$  or  $c$  were provided for their counterparts. These definitions of  $t_{1gr}$ ,  $t_0$ ,  $c_0$ , and  $c_1$  are essential for determining the validity of T/C ratios and must be provided.

Pages 11-13. Definitions of  $T_{1g}$ ,  $T_0$ ,  $C_0$ , and  $C_1$  are provided. Using the parameterization of a CJS model,  $T_0$  has the expected value

$$\begin{aligned} E(T_0) &= E\left[X_{12} + \frac{X_{102}}{S_2} + \frac{X_{1002}}{S_2 S_3} + \frac{X_{10002}}{S_2 S_3 S_4}\right] \\ &= R_1 S_1 \left[p_1 T_1 + (1-p_1) p_2 T_2 + (1-p_1)(1-p_2) p_3 T_3 + (1-p_1)(1-p_2)(1-p_3) p_4 T_4\right] \end{aligned}$$

which is consistent with the definition of

“PIT tagged CSS smolts routed to the fish barge (or truck) at LGR or first-time detected PIT tagged smolts routed to transportation at either LGS, LMN, or MCN dams.”

For  $T_{1gr}$

$$E(T_{1gr}) = R_1 S_1 p_1 T_1$$

which is again consistent with the definition of PIT tagged CSS smolts “transported at just LGR dam.”

For  $C_0$

$$\begin{aligned} E(C_0) &= E\left[R_1 S_1 - \left(m_{12} + \frac{m_{13}}{S_2} + \frac{m_{14}}{S_2 S_3}\right) - 2\Delta_0\right] \\ &= R_1 S_1 (1-p_1)(1-p_2)(1-p_3) - E(2\Delta_0) \end{aligned}$$

which is again consistent with the definition of “smolts that were not detected at any of the collector projects.” Note the value 2 is an arbitrary constant to adjust for an assumed 50% survival rate from LGR to lower Columbia dams.

For  $C_1$

$$E(C_1) = E \left[ (m_{12}\delta_2) + \frac{(m_{13} - \delta_3)}{S_2} + \frac{(m_{14} - \delta_4)}{S_2 S_3} - 2\Delta_1 \right]$$

$$= R_1 S_1 \left[ p_1 (1 - T_1) + (1 - p_1) p_2 (1 - T_2) + (1 - p_1)(1 - p_2) p_3 (1 - T_3) \right] - 2E(\Delta_1)$$

which is *not* consistent with the definition of “hatchery fish that were detected *one or more times* while migrating through the hydrosystem” (p. 13, line 9). The expected value of  $C_1$  indicates it includes only fish detected the first time at LGR, LGO, or LMO and *not* all possible downstream detection histories as so defined. Either the definition of  $C_1$  needs to be changed or the value of  $C_1$  reformulated (Equation 6) to include all fish detected “one or more times.” The fact  $C_1$  is either defined wrong or calculated wrong reemphasizes the need to know how the returning adult numbers were calculated.

In the above calculations of expected values,  $T_i$  is the probability of transport,  $p_i$  is the probability of detection at the  $i$ th site.

Page 13, last paragraph. A Monte Carlo approach to confidence interval estimation is an acceptable approach as long as all sources of variability are incorporated. Unfortunately, the Monte Carlo approaches described by Equations 7-9 are inadequate and need to be revised to provide valid interval estimates. For example, in calculating the variance of  $T_0$  defined as

$$T_0 = X_{12} + \frac{X_{102}}{S_2} + \frac{X_{1002}}{S_2 S_3} + \frac{X_{10002}}{S_2 S_3 S_4}, \quad (\text{Eq. 4})$$

the Monte Carlo method (Equation 7) uses only

$$T_0 = X_{12} + \frac{X_{102}}{rv(S_2)} + \frac{X_{1002}}{rv(S_2 S_3)}.$$

First, the fourth term in Equation (4) is seemingly being ignored in the interval estimation. Second, the values  $X_{12}$ ,  $X_{102}$ ,  $X_{1002}$ , and  $X_{10002}$  are themselves multinomial random variables. The Monte Carlo method must take into account not only the uncertainty in the survival estimates (i.e.,  $\hat{S}_i$ 's) but also the stochastic variability in the observed counts (i.e.,  $X_{12}$ ,  $X_{102}$ , etc.)

As described, the Monte Carlo method used in the report is vastly underestimating the uncertainty in the estimates of SARs and T/C ratios, and need to be

reformulated and recalculated. To prove this point, consider only the second term in Equation (4)

$$\text{Var}\left(\frac{X_{102}}{\hat{S}_2}\right) = \text{Var}_2\left[E_1\left(\frac{X_{102}}{\hat{S}_2}\middle|2\right)\right] + E_2\left[\text{Var}_1\left(\frac{X_{102}}{\hat{S}_2}\middle|2\right)\right]$$

where 1 denotes the sampling error in estimating  $\hat{S}_2$  and 2 denotes the stochastic variability in  $X_{102}$ . Then

$$\text{Var}\left(\frac{X_{102}}{\hat{S}_2}\right) = \text{Var}_2\left[X_{102} \cdot E_1\left(\frac{1}{\hat{S}_2}\middle|2\right)\right] + E_2\left[X_{102}^2 \text{Var}_1\left(\frac{1}{\hat{S}_2}\middle|2\right)\right].$$

Using first-term Taylor series approximations

$$\begin{aligned}\text{Var}\left(\frac{X_{102}}{\hat{S}_2}\right) &\doteq \text{Var}_2\left[\frac{X_{102}}{\hat{S}_2}\right] + E_2\left[X_{102}^2 \frac{\text{Var}(\hat{S}_2)}{\hat{S}_2^4}\right] \\ &\doteq \frac{1}{S_2^2} \cdot R_1 S_1 (1-p_1) S_2 p_2 (1-S_1 (1-p_1) S_2 p_2) \\ &\quad + \frac{\text{Var}(\hat{S}_2)}{S_2^4} \cdot \left[ R_1 S_1 (1-p_1) S_2 p_2 (1-S_1 (1-p_1) S_2 p_2) - (R_1 S_1 (1-p_1) S_2 p_2)^2 \right]\end{aligned}$$

using the CJS parameters. The method described in the report incorporates only the component  $\text{Var}_1\left(\frac{1}{\hat{S}_2}\middle|2\right)$  and none of the remaining sources of variation.

Page 15, Calculation of SARs with confidence intervals. The Monte Carlo method for calculating the SAR in this paragraph must be corrected for the additional uncertainty in calculating the denominators  $T_{1g}$ ,  $T_0$ ,  $C_0$ , or  $C_1$  as described above. Again, the described Monte Carlo method will underestimate the true width of a 95% confidence interval and must be corrected.

Page 17, Table 1. The symbols  $T_0$  and  $C_0$  should have “hats” to denote these are estimates, i.e.,  $\hat{T}_0$  and  $\hat{C}_0$ . Furthermore, either the standard errors or CI for these values should be reported along with the point estimates in the table.

Page 17, Table 2. Again, standard errors should be reported along with the point estimates. I suggest using the delta method to approximate the variance. Similar comments pertain to the tables throughout the report (e.g., Tables 5, 6, etc.).

Page 22, Table 5. Justification for the use of the geometric mean to summarize results across years needs to be provided in the methods section. Why is this calculation of central tendency recommended over an arithmetic or weighted average? Table 5 uses both geometric as well as arithmetic means in summarizing the same data. What is the justification for using arithmetic means across hatcheries and geometric means across years?

Page 23, Table 7. It is unclear how these values were calculated for this table. For example,  $T_0$  LGR-LGR for hatchery fish in 1997 was 0.77% (Table 5), while  $T_0$  LGR-LGR for wild smolts was 1.71% (Table 6), the difference being  $1.71 - 0.77 = 0.94$ , while Table 7 reports 121.96% as the “difference.” Provide a formula to describe the estimates in Table 7.

I further recommend rather than taking the “differences,” calculate the ratios, e.g.,

$$\frac{1.71}{0.77} = 2.22$$

suggesting wild fish return at a rate of 2.22:1 compared to hatchery fish. Ratios are more consistent with the multinomial models that are the basis of SARs and T/C ratios. It appears the actual method of calculation in Table 7 is

$$\left( \frac{T_{\text{Wild}}}{T_{\text{Hatchery}}} - 1 \right) 100\%$$

Clarification is required!

Following is a table with revised estimates for Table 7 based on the ratio of wild to hatchery SARs. Data taken from Tables 5, 6, and 8.

Year	$T_0$		$C_0$	
	LGR-LGR	BON-LGR	LGR-LGR	BON-LGR
1997	2.22	2.22	2.93	2.26
1998	0.93	0.93	1.21	1.02
1999	1.07	1.07	1.38	1.43
Geometric Mean	1.30	1.30	1.70	1.49

This suggests wild smolts return at a ratio 1.3:1 or 1.7:1 compared to hatchery fish.

Page 25, Table 9. For purposes of clarity, the T/C ratio should *not* be identified by symbols such as  $T_0 / C_0$  but rather as  $\text{SAR}_{T_0} / \text{SAR}_{C_0}$ , should one mistakenly believe the T/C ratio is simply calculated as a function of Equations 4-6. This notation is a bit more awkward but true to the correct calculation of the T/C ratio.

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Page 26, Table 10. Standard errors or confidence intervals for the annual T/C ratio are important for overall interpretation. Including or excluding the 1994 T/C ratio based on the highest value is unjustified unless it can be shown to be an outlier due to handling mishaps, lack of data QA/QC, or extraordinary sampling noise. The text gives no objective reason for excluding it from the overall interpretation of this study.

Sincerely,



John R. Skalski  
Professor of Biological Statistics

Attachment

cc: Pat Poe, BPA